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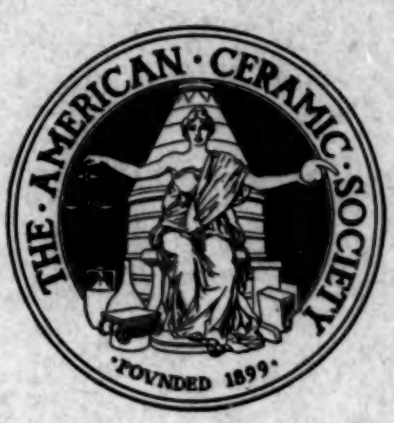

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KINETICS OF SOLID-PHASE REACTIONS OF CERTAIN CARBONATES WITH MULLITE, SILICA, AND ALUMINA*

By Gordon R. Pole and Nelson W. Taylor

Abstract

Quantitative measurements of the rates at several temperatures of reactions between carefully sized solids have been made by determining the amount of CO_2 evolved as a function of the time. While the absolute rate is a function of grain size and other factors, the temperature coefficient gives a constant characteristic of the chemical system involved. The reaction product is found to lessen the speed of reaction in accordance with the relation, $dy/dt = k/y$, where y is the thickness of the layer of reaction product. Under comparable conditions, sodium carbonate attacks mullite most easily, with less attack on quartz, and least on corundum. The activity of calcium carbonate on mullite, quartz, and corundum is considerably less marked. Applications to glass melting and to corrosion of refractories by alkali or alkali-earth dusts are discussed. A table of values of the function, $F = \left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$, for positive integral values of x from 1 to 100 is included.

I. Introduction

Although reactions between solids play an important rôle in many ceramic operations, relatively little attention has been given to the quantitative study of their mechanism. A knowledge of this mechanism would be of importance from several viewpoints. On the theoretical side it will lead to a better understanding of the forces binding the component molecules, atoms, or ions in crystals, and on the practical side it may point the way toward bringing about composition and structure changes with greater ease and efficiency than is now possible. A general review of the field has been published by Taylor.[1]

The widespread interest in corrosion of refractories by dusts and vapors has led to the choice of alumina, silica, and mullite with certain carbonates as the system for study and report at this time.

(1) Historical

Some of the earliest work on the kinetics of solid-phase reactions was done by Tammann[2] in 1920. He assumed that the rate of increase in thickness of a compound formed at the boundaries between two reacting crystal phases was inversely proportional to the time. He gives the expression for this type of reaction as $dy/dt = b/t$, where y is the thickness of the compound formed at the boundaries and t is the time. Upon integrating, the expression $y = b \ln t +$ constant is obtained.

In 1927, Jander[3] published some work on the kinetics of solid-phase reactions between crystalline materials. He found from actual experimental determination that Tammann's expression was not correct. As a result of these studies, he came to the conclusion that the square of the thickness of the reacting layer between two crystal phases was proportional to the time, if the process was conducted isothermally. Expressed mathematically, he obtained the expression, $dy/dt = k/y$, where y is the thickness of the reacting layer and t is the time. Upon integrating this equation, Jander obtained the expression

$$y^2 = 2kt + \text{constant} \qquad (1)$$

Equation (1) states that the square of the thickness of the growing layer or zone of reaction product is directly proportional to the time. In this case, the product formed by the reaction thickens at a rate inversely proportional to the existing thickness of the layer. In other words, the product of the reaction acts as a diffusion barrier and tends to retard the reaction as the thickness increases.

For convenience, the solid-phase reaction given by Jander in equation (1) will be called case (1). There are two other possible cases of solid-phase reactions which are given by the following equations.

Case (2) is a solid-phase reaction in which the boundary moves at a constant speed and in which the product of the reaction offers no retarding or catalytic effect. This is expressed in the equation $dy/dt = k$ or, upon integrating,

$$y = kt + \text{constant} \qquad (2)$$

A good example of case (2) is given in the rate of calcination of limestone[4] in which the reaction $CaCO_3 \longrightarrow CaO + CO_2$ takes place.

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* Presented as part of the Symposium on "Factors Affecting Rates of Change in Refractory Systems," Annual Meeting, American Ceramic Society, Buffalo, New York, February, 1935 (Refractories Division). Received March 21, 1935.

Submitted by Gordon R. Pole as partial fulfillment of the requirements for the degree of Doctor of Philosophy at The Pennsylvania State College.

[1] N. W. Taylor, "Reactions between Solids in the Absence of a Liquid Phase," *Jour. Amer. Ceram. Soc.*, **17** [6] 155–63 (1934).

[2] G. Tammann, *Z. anorg. allgem. Chem.*, **111**, 78 (1920); **123**, 196 (1922).

[3] W. Jander, *ibid.*, **163**, 1 (1927); **166**, 31 (1927).

[4] C. C. Furnas, "Rate of Calcination of Limestone," *Ind. Eng. Chem.*, **23**, 534–38 (1931).

In case (3), the solid-phase reaction is catalyzed by the product of the reaction, and the rate of growth of the product is directly proportional to the thickness. This reaction is expressed by the equation $dy/dt = ky$ or, upon integrating,

$$\ln y = kt + \text{constant} \qquad (3)$$

A possible type for case (3) would be an explosive or autocatalytic type of reaction.

The experimental work given in this paper, however, is concerned only with case (1) as given by Jander in equation (1). The other cases are cited merely to show other types of rate phenomena involving solids.

The connection between the time-rate of increase in thickness of the reacting layer and the percentage of reaction is obtained by Jander in the following manner.

If r equals the average radius of grain of crystal phase which is present in the smaller amount and x is percentage of reaction, then the relation between x and the thickness, y, of the reaction layer is given by the expression,

$$\frac{4\pi r^3/3 - 4\pi(r-y)^3/3}{4\pi r^3/3} = \frac{x}{100}$$

Solving for y,

$$y = r\left(1 - \sqrt[3]{\frac{100-x}{100}}\right)$$

Squaring this expression,

$$y^2 = r^2\left(1 - \sqrt[3]{\frac{100-x}{100}}\right)^2$$

Substituting the value of $y^2 = 2kt$ in the above expression, the final expression used by Jander is obtained to express the kinetics of solid-phase reactions in which a gas is given off during the reaction,

$$\left(1 - \sqrt[3]{\frac{100-x}{100}}\right)^2 = \frac{2kt}{r^2} = Kt \qquad (4)$$

Where x = per cent conversion as measured by cc. of gas evolved
t = time
r = average radius of particle size of reacting mixture.

The constant, k, contains the diffusion coefficient, D, and the concentration, C_0, of the diffusing component at the interface.

Jander and Braune expressed the relation between the velocity of reaction and temperature by the exponential equation,

$$K = Ce^{-q/RT} = Ce^{-a/T} \qquad (5)$$

Where T = absolute temperature
R = gas constant (calories)
C = a constant (which depends in part upon the number of mobile particles and the physical state of the material, such as the intimacy of contact and other factors that have not been determined)
q = energy in calories which is necessary to activate a gram molecule of particles so it can move from point to point in the crystal lattice; this quantity is called the "work of loosening" or "energy of activation."

This equation was substantiated by Fischbeck[5] in his work on solid-phase reactions of certain crystalline materials. Jander further confirmed the relation by investigating a series of simple solid-phase reactions involving silicates. The reactions studied were as follows:

$$CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2$$
$$BaCO_3 + SiO_2 \longrightarrow BaSiO_3 + CO_2$$
$$CaCO_3 + MoO_3 \longrightarrow CaMoO_4 + CO_2$$

In all of the above equations the percentage of reaction at a given temperature was determined by measuring the amount of CO_2 evolved at a constant pressure in a given length of time. These values were then substituted in equation (4) and plotted against the time. The slope of the curve gives K for that temperature. By determining a number of K values and plotting the logarithms of these values against the reciprocal of the absolute temperature, a straight line is obtained, the slope of which leads to the value of a. The a value multiplied by R in calories gives q, the "work of loosening." Then with the aid of equation (5), by substituting the value of a and K, the value of C is found.

For the reaction between $BaCO_3$ and SiO_2 (1:10), with an average diameter of the grain equal to 0.00875 centimeter, Jander obtained the following values:

$$K = 2630e^{-20,500/T}$$
q = 40,800 calories per mol.

Where K = a constant (which depends on the diffusion coefficient, D, and the radius of particle, r, as well as the concentration gradient across the phase boundary)

II. Plan of Research

The method chosen for studying the kinetics of solid-phase reactions between the carbonates of sodium and calcium and the refractory compounds, mullite, silica, and alumina, is similar to that used by Jander. It was decided to study the reaction rates of sodium carbonate with these compounds at 750°C, 700°C, 650°C, and 600°C and those of calcium carbonate at 600°C, 550°C, and 500°C with the same compounds. The reason for this was that the decomposition pressures at the maximum temperature for the two carbonates was in each case so low that its effect on the reaction velocity was negligible. The decomposition pressure for sodium carbonate at 750°C and for the calcium carbonate at 600°C are given in the International Critical Tables as follows:

Na_2CO_3	750°C	0.0030	atmosphere
$CaCO_3$	600°C	0.00242	atmosphere

In order to eliminate one variable, a grain size between 150- and 200-mesh throughout the test was used. As may be seen in equation (4), the slope of the K curve is affected materially by the size of particles of the reacting materials.

[5] K. Fischbeck, *Z. Elektrochem.*, **39**, 316–30 (1933).

III. Preparation of Materials

The materials used in this investigation consisted of crystalline quartz, corundum, mullite, sodium carbonate, and calcite.

(1) Quartz

The quartz was Brazilian crystal and chemical analysis showed that it contained less than 0.5% impurities. The material was ground in an agate mortar and sieved through copper screens. Only the material that passed a 150-mesh and remained on a 200-mesh screen was then heated for 2 hours at approximately 830°C to oxidize any lint or foreign material and also to drive off all adsorbed moisture. The material was then put in a stoppered vial and placed in a desiccator.

The 200-mesh quartz used in the $BaCO_3$–SiO_2 reaction was heated at 850°C for 16 hours previous to using.

(2) Alumina

The crystalline corundum was Burrell's Blue Label, alkali-free, 90-mesh Alundum. The material was ground in an agate mortar and screened in the same way as the quartz to obtain a 150- to 200-mesh sizing. The 150- to 200-mesh material was then treated at room temperature for 10 minutes with 48% hydrofluoric acid to eliminate any silica that might have come from the grinding in the agate mortar. The treated material was thoroughly washed and heated for one hour between 900°C and 1000°C by a blast burner in a platinum crucible. A microscopic examination showed the material to be essentially free of impurities.

(3) Cristobalite

The mullite used was prepared in the laboratory from a mixture of cristobalite and amorphous alumina with a small amount of lime. Two different materials were used in making the cristobalite. In one case, 0.3 gram of CaO was added to 15 grams of Brazilian quartz, ground to pass 100-mesh, and the material was mixed by grinding wet in an agate mortar. After drying, the material was broken up and pressed into a cake under a pressure of 8000 pounds per square inch. The cake was heated in a small tube furnace to 1540°C and held for 4 hours. The sintered button was then broken up in a diamond mortar and ground in an agate mortar to pass a 200-mesh sieve. Any iron that might have come from the diamond mortar was removed with a magnet. Upon examining the material with the microscope, it was estimated that the material was about 95% cristobalite. The index of refraction was slightly greater than 1.485 with a low birefringence.

The second sample of cristobalite was prepared by mixing 25 grams of Merck's C.P. silicic acid and 0.3 gram of CaO by grinding wet in an agate mortar. After drying, the material was broken up and pressed into a cake under 8000 pounds pressure. The cake was then heated in a gas-fired tube furnace and held at 1540°C for 2 hours. The sintered mass was broken up and sieved through a 200-mesh screen in the same manner as that employed for the first sample. A microscopic examination gave an isotropic material with an index slightly higher than 1.485. Both of these samples of cristobalite were used in the preparation of mullite batches, the first being designated as No. 1 and the second as No. 2.

(4) Mullite

In preliminary experiments of preparing mullite from cristobalite and crystalline alumina with a small amount of lime present (2 to 3%), it was found best to work with batches that were in the composition triangle mullite-anorthite-silica of the lime-alumina-silica phase diagram. This eliminated any possibility of corundum precipitating out as it is not a stable phase except above about 1700°C. It was also found that in the preparation of mullite it is almost impossible to get all of the alumina into solution if one starts with a crystalline corundum.

After some advice from J. W. Greig of the Geophysical Laboratory, it was decided to make a series of mullite mixes using an amorphous alumina prepared from C.P. aluminum nitrate.

The nitrate was first dehydrated at 200°C and then ignited for one hour at 400°C in an electric muffle to drive off all the water and nitric oxide. Microscopic examination showed the material to be finely divided and entirely amorphous.

This amorphous alumina was then used to make up the following batches for the preparation of mullite:

Mullite Mix No. 1B

6.15	grams	Al_2O_3 (from C.P. aluminum nitrate)
3.65	"	cristobalite No. 2
0.20	"	CaO (prepared from Baker's C.P. $CaCO_3$)

Mullite Mix No. 2B

6.15 grams Al_2O_3 (from C.P. aluminum nitrate)
3.65 " cristobalite No. 1
0.20 " CaO (prepared from Baker's C.P. $CaCO_3$)

Mullite Mix No. 4B

6.15 grams Al_2O_3 (from C.P. aluminum nitrate)
4.47 " Merck's C.P. silicic acid
0.20 " CaO (prepared from Baker's C.P. $CaCO_3$)

Mullite Mix No. 5

9.8 grams mineral sillimanite (from A. P. Honess, Geology Department)
0.2 " CaO (prepared from Baker's C.P. $CaCO_3$)

Previous to firing, these batches were ground wet in an agate mortar and dried. After pressing into 1-inch pills by means of a hydraulic press at 8000 to 10,000 pounds per square inch, they were fired in the gas-fired tube furnace.

Batches Nos. 1B, 2B, and 4B were first fired together for 8 hours between 1480°C and 1540°C. The pills were then reground to pass a 200-mesh sieve and pressed into cakes. They were again fired for 8 hours between 1540°C and 1600°C. The sintered pills were then ground to pass a 200-mesh sieve and examined with the microscope. All three batches showed a large amount of quite large mullite crystals, fairly free from corundum, in a glassy matrix. It was felt that longer heating would cause further crystal growth so the batches were re-pressed into pills and heated on five different days for periods of 6 hours at a temperature between 1540°C and 1600°C. The sintered pieces were then ground to pass a 150-mesh sieve and examined with the microscope. The heat treatment had increased the size of the mullite crystals and the amount of mullite was estimated to be between 75 and 80%.

Mullite mix No. 5, which consisted of a fairly pure sample of finely ground sillimanite and 2% lime, was used to determine whether or not there was any difference between the mullite formed by the two methods. This batch was first heated to 1540°C and held for 11 hours. It was then ground to pass a 150-mesh sieve and examined with the microscope. The material showed a large amount of very fine mullite crystals. This sample was then re-pressed into a pill and heated at 1600°C for five hours and after cooling was heated again for six hours between 1600°C and 1650°C. After grinding to pass 150-mesh, the material was again examined under the microscope. The mullite crystals had grown to fairly large sizes and there was little evidence of free corundum. No differences in the mullite, formed by this means and by the other three methods, could be detected.

All four samples were then treated separately with 48% hydrofluoric acid for six hours at 0°C to remove all the glassy matrix. After treatment, they were filtered and washed with distilled water and dilute hydrochloric acid and finally by distilled water. The samples were then dried and ignited at 900° to 1000°C in a platinum crucible for one hour. Microscopic examination showed evidence of a slight amount of glass. Mixes Nos. 1B, 4B, and 5 had fairly large well-developed crystals of mullite with only small traces of corundum. The mullite was estimated to be between 95 and 98% pure. Sample No. 2B was fairly good, but the crystals of mullite were not as well developed as in the other three. In order to remove the last traces of glass, samples Nos. 1B, 4B, and 5 were given a second treatment of 40% hydrofluoric acid at 0°C for 2 hours. After washing thoroughly with distilled water, the blended materials (Nos. 1B, 4B, and 5) were heated in a platinum crucible for one hour at 900° to 1000°C.

(5) Microscopic and X-Ray Examination of Synthetic Mullite

The mullite was then examined with the microscope and was found to be practically free from glass. The material was a mass of needle-shaped crystals that had parallel extinction and the index of refraction was slightly less than 1.645. A direct comparison was made with a sample of mullite prepared by J. W. Greig of the Geophysical Laboratory and the optical characteristics of the two materials were found to be practically identical.

X-ray diffraction patterns of the two different mullite samples were made by F. J. Williams of this laboratory, using the powder-diffraction method. The X-ray tube was of the gas-discharge type, similar to that of Ksanda.[6] The tube had a copper target from which the K-alpha and K-beta radiations were used without a filter. The camera had a diameter of 57.65 millimeters and the powdered specimen was mounted on a fine copper wire of which the X-ray pattern served as a means of calibrating the film. Neither of the spectrographs showed corundum lines. The corresponding strong lines of both mullite samples

[6] C. J. Ksanda, *Rev. Sci. Instruments*, 3, 531–34 (1932).

checked quite closely as to line position and relative intensity.

Figure 1 is a graph of the X-ray data showing a comparison between the various lines for the two mullite preparations, from which it can be readily seen that the two materials show a good agreement for the corresponding strong lines.

(6) Reaction Mixtures for Rate Studies

The powdered mullite prepared in the laboratory was sieved through copper screens to obtain a grain size that would pass a 150-mesh sieve and remain on a 200-mesh sieve. This would correspond to an opening of 0.104 millimeter for the 150-mesh sieve and 0.074 millimeter for the 200-mesh sieve. The Geophysical Laboratory mullite was so fine grained that it all passed a 200-mesh sieve, and it was used in this form.

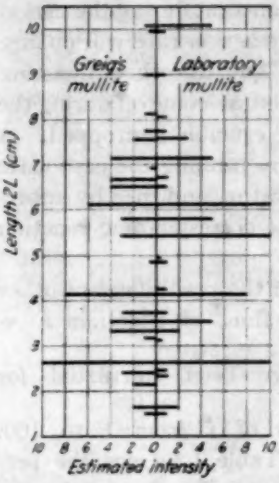

FIG. 1.—Line spacings and intensities in X-ray diffraction patterns.

Baker and Adamson's C.P. anhydrous sodium carbonate was used in all experiments. The powdered material was sieved through copper screens to obtain a 150- to 200-mesh sizing and then heated in a platinum crucible for four hours at 300°C to remove any adsorbed moisture and also to decompose any bicarbonate present. The dried material was put in a stoppered vial and placed in a desiccator.

The calcium carbonate used in these experiments was prepared from a clear crystal of calcite (obtained from A. P. Honess of the Geology Department). The crystal was ground in an agate mortar and sieved to obtain a 150- to 200-mesh sizing. The screened material was then heated for four hours at 430°C to remove any adsorbed moisture, put in a stoppered bottle, and placed in a desiccator.

IV. Apparatus

The apparatus used for these experiments was similar in design to the one Jander employed for his reaction-rate studies on $BaCO_3 + Cb_2O_5$. A drawing of the apparatus with its principal parts is shown in Fig. 2.

A, the furnace part, consists of a $^3/_{16}$- by $1^3/_8$- by 11-inch Alundum tube wound with 20 feet of No. 22 Chromel-A resistance wire. The wires are covered with a thin coating of Alundum cement and insulated by $3^1/_2$ inches of insulating material consisting of rings cut from Babcock and Wilcox No. 80 insulating brick and then packed on the outside with Sil-O-Cel powder. The whole assembly is contained in an $8^1/_2$- by 11-inch sheet-metal can with Transite covers on the ends. The furnace is connected in series with 19- and 22-ohm variable resistances in parallel. The furnace is controlled manually by maintaining a

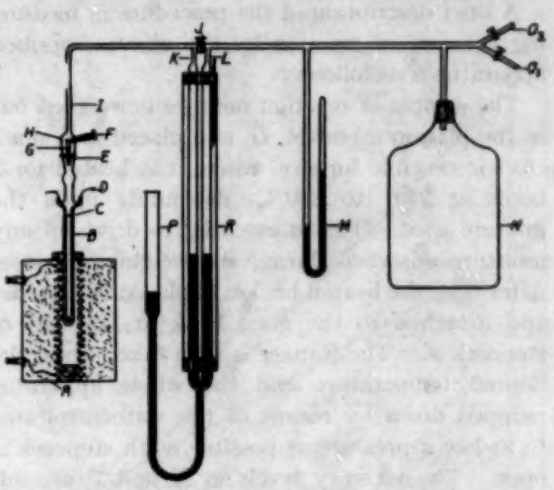

FIG. 2.—Apparatus for measuring rate of evolution of gas.

constant current during the 2 hours' run necessary for each experiment. The variation in temperature did not exceed 5°C after the first five minutes for most of the determinations and was generally much less. *B* is a $^{11}/_{16}$- by 11-inch No. 6060 mullite tube (made by the Champion Spark Plug Co.). The tube has a $^1/_2$-inch diameter and is sealed directly to the Pyrex-brand glass tube, *C*, by means of a butt weld. The joint is vacuum-tight and has given good service for over six months. An insulated Pt–Pt 10% Rh calibrated thermocouple is sealed through the Pyrex-brand glass tube at *D*. The couple extends down the sides of tube *B* with the junction bead projecting upward through a small insulator at the bottom. The lead wires of the thermocouple run to mercury contact wells placed in a vacuum "cold junction" bottle. The lead wires from the cold junction bottle connect to a Leeds and Northrup portable potentiometer and to a type-K potentiometer. This arrangement gave close control of the temperature during a reaction. *E* is a $^1/_2$- by $1^1/_2$-inch Pyrex-brand standard tapered ground-glass joint connecting the reaction tube, *B*, with the small Pyrex-brand glass chamber, *H*. *F* is a $^1/_4$- by 1-inch Pyrex-brand tapered ground-glass stopcock with a small glass hook sealed to the end. *G* is a $^1/_4$- by $1^1/_2$-inch platinum bucket with a bail, hanging from the glass hook on the end of stopcock, *F*. This part of the apparatus is connected by a $1^1/_2$-millimeter

capillary tube, I, to a three-legged mercury manometer, K, L, and P. A stopcock, J, is placed between the two legs, K and L. The tubes, K and L, are 24 inches long and are surrounded by a glass water jacket, R. Tube K has a scale etched in tenths of a centimeter up to 50 centimeters. A Pyrex-brand capillary tube connects the manometer to the $^1/_4$- by 15-inch absolute mercury pressure gage, M, and then to the 10-liter gas balloon, N. The gas balloon is insulated with one inch of asbestos magnesia cement. The capillary tube then extends to a Y with stopcocks, O_1 and O_2, at the ends. Stopcock O_1 connects to a water-aspirator pump, and O_2 to the outside air through a desiccator tube.

V. Experimental Procedure

A brief description of the procedure in measuring the rate of reaction by the above described apparatus is as follows:

The sample of reaction mixture is weighed out in the platinum bucket, G, and placed in a small electric crucible furnace, where it is heated for 2 hours at 240° to 300°C, depending upon the mixture used. This is essential to drive off any moisture adsorbed during the weighing process. After this, the heated bucket is placed in a holder and attached to the glass hook at the end of stopcock F. The furnace is then taken up to the desired temperature and the whole apparatus pumped down by means of the water aspirator to as low a pressure as possible, with stopcock J open. The mercury levels in K and L are adjusted to the zero reading on N by raising or lowering the reservoir, P. The apparatus is then tested for leaks by closing stopcock J. If the mercury columns change levels, it indicates that the apparatus is not vacuum-tight. The system is allowed to stand in this condition for 8 to 12 hours so that it may come to a temperature equilibrium. After this procedure the run is ready to be made. Stopcock O_2 is opened until the desired pressure is obtained by reading gage M. The mercury levels in K and L are adjusted to read zero and stopcock J is closed. The temperature of the tube, B, is read on the potentiometer and the temperature of the water jacket, R, is recorded. The stopcock, F, is turned to drop the bucket, G, and a stop-watch is started at the same instant. Readings of the volume of gas evolved are then taken every 20 seconds for the first minute by leveling the two mercury columns, K and L, with the reservoir, P. After the first minute, readings are taken every minute up to 10 minutes and after that every 5 minutes up to 30 minutes. After 30 minutes it is necessary to read only at 10-minute intervals. The temperature is recorded simultaneously with each volume reading. It is usually necessary to take readings for a period of 2 hours. The temperature always falls sharply when the bucket first drops, but by the end of 4 minutes it is back again to a constant temperature. The gas balloon, N, acts as a reservoir to prevent a change in pressure during the reaction. The actual pressure change in the gas balloon for a 50-cubic centimeter volume change in K is about 1 part in 200. At 40 millimeters pressure, this would amount to 0.2 millimeter of mercury. It is important that the temperature remain constant during the period of a run; otherwise the reaction rate will change with the temperature. Any adsorbed moisture or gases in the reaction mixture come off during the first 40 seconds after the crucible is dropped. A correction can be made by running the carbonate alone at the given temperature and then by applying this correction to the corresponding reaction mixture used.

For the convenience of the reader and of other workers in this field, values of function $F = \left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$ have been calculated for positive integral values of x from 1 to 100. These are exhibited in Table I. Once the per-

TABLE I

VALUES OF FUNCTION $F = \left(1 - \sqrt[3]{\frac{100-x}{100}}\right)^2$ FOR POSITIVE INTEGRAL VALUES OF x FROM 1 TO 100

x	F ($\times 10^{-4}$)	x	F ($\times 10^{-3}$)	x	F ($\times 10^{-3}$)	x	F ($\times 10^{-3}$)
1	0.109	26	0.912	51	4.477	76	14.33
2	0.449	27	0.992	52	4.709	77	15.00
3	1.020	28	1.096	53	4.951	78	15.71
4	1.823	29	1.164	54	5.203	79	16.45
5	2.890	30	1.257	55	5.462	80	17.24
6	4.162	31	1.353	56	5.731	81	18.07
7	5.712	32	1.454	57	6.012	82	18.96
8	7.508	33	1.563	58	6.305	83	19.89
9	9.548	34	1.672	59	6.610	84	20.89
10	11.90	35	1.790	60	6.927	85	21.97
11	14.52	36	1.910	61	7.258	86	23.12
12	17.39	37	2.036	62	7.601	87	24.34
13	20.61	38	2.170	63	7.958	88	25.69
14	24.01	39	2.307	64	8.329	89	27.13
15	27.77	40	2.452	65	8.720	90	28.71
16	31.92	41	2.602	66	9.120	91	30.46
17	36.24	42	2.756	67	9.548	92	32.39
18	40.96	43	2.921	68	9.986	93	34.56
19	45.97	44	3.087	69	10.45	94	37.03
20	51.41	45	3.265	70	10.93	95	39.89
21	57.15	46	3.448	71	11.43	96	43.30
22	63.20	47	3.637	72	11.96	97	47.51
23	69.56	48	3.838	73	12.51	98	53.09
24	76.39	49	4.040	74	13.08	99	61.56
25	83.54	50	4.256	75	13.69	100	100.00

centage reaction, x, has been determined, the corresponding value of F may be read off or interpolated from the table.

One can now calculate from the data obtained the percentage of reaction, x, for each given time period. Then by substituting these values for x in the expression $\left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$, or reading from Table I and plotting these values against the corresponding times, K can be determined from the slope of a straight line drawn through the given points. K will have a different value for each temperature so that by making several runs with the same reaction mixture at different temperatures, a number of values of K can be determined. Then if log K is plotted against the reciprocal of the absolute temperature, the a value can be determined from the slope of the straight line drawn through these points. The relation is given by the equation

$$K = Ce^{-a/RT} = Ce^{-a/T}.$$

A detailed presentation of data now follows.

TABLE II

Reaction mixture = $SiO_2 + Na_2CO_3$ (2:1)
Mean temperature of reaction = 748°C
Weight of charge = 0.100 gram
Particle size = 150- to 200-mesh
Temperature of water jacket = 24°C
Pressure gas balloon = 40 mm.

$K = 0.575 \times 10^{-5}$

Time (t)	Vol. CO_2 (cc.)	Temp. (°C)	Calculated reaction x (%)	$\left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$
0	0	749	0	0
20 sec.	1.7	687	0.81	0.07×10^{-5}
40 "	4.0	725	1.91	0.41 "
60 "	6.3	735	3.01	1.02 "
2 min.	8.4	740	4.01	1.82 "
3 "	8.8	744	4.20	2.02 "
4 "	9.2	747	4.39	2.20 "
5 "	9.6	747	4.59	2.41 "
6 "	9.9	748	4.73	2.57 "
7 "	10.2	748	4.87	2.73 "
8 "	10.5	748	5.01	2.89 "
9 "	10.7	748	5.11	3.01 "
10 "	10.9	748	5.21	3.12 "
15 "	11.5	748	5.49	3.50 "
20 "	12.4	748	5.92	4.04 "
25 "	13.1	748	6.26	4.54 "
30 "	13.9	748	6.64	5.16 "
40 "	14.5	748	6.93	5.61 "
50 "	15.5	748	7.40	6.42 "
60 "	16.0	748	7.64	6.84 "
70 "	16.5	748	7.88	7.27 "
80 "	17.0	748	8.12	7.75 "
90 "	17.5	748	8.36	8.24 "
100 "	18.2	750	8.69	8.93 "
110 "	19.0	750	9.07	9.73 "
120 "	19.4	750	9.27	10.23 "

VI. Reaction Velocity of SiO_2 (Quartz) + Na_2CO_3 (2:1)

The materials used for these reactions were screened to give a 150- to 200-mesh grain sizing. The silica and sodium carbonate were weighed out in the molecular proportion of 2 to 1 and then mixed by stirring with a spatula and passing four times through an 80-mesh sieve.

Reaction rates for this mixture were determined at 646°C, 702°C, 728°C, 748°C, and 758°C. At temperatures above 725°C, 0.1 gram of the reaction mixture was used, while below this temperature a 0.2-gram charge was used. The results of the determinations at 748°C are presented in Table II. A graph of the function $\left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$, *versus* time for the last four temperatures is given in Fig. 3.

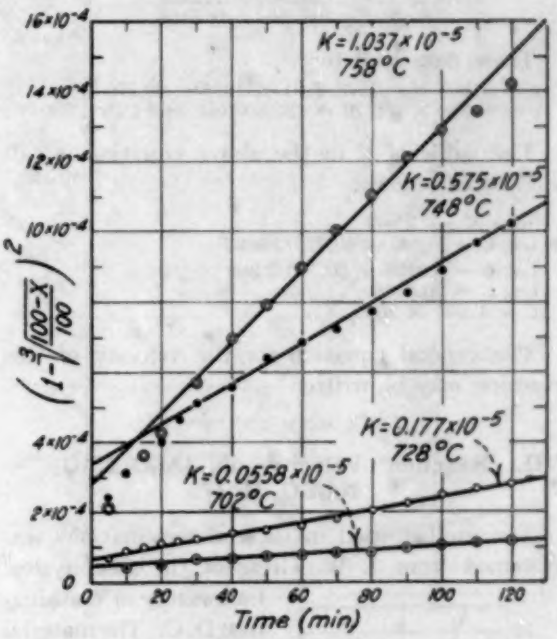

FIG. 3.—Rate data on 150- to 200-mesh quartz + Na_2CO_3 (2:1).

It was found at the lower temperatures, 646°C and 702°C, where the reaction proceeds very slowly, that the determinations of the reaction velocities were not very accurate, possibly due to small amounts of adsorbed moisture and to the lack of delicacy of the instrument to record the small volume changes. A greater accuracy could possibly be obtained by using a larger sample of the reaction mixture at lower pressures.

Figure 4 is a graph of log K against $1/T$ for the $SiO_2 + Na_2CO_3$ reaction. It can be seen that a straight line will pass through the three upper points corresponding to 758°C, 748°C, and 727°C. The slope of this straight line multiplied by 2.303 gives the a value in the expression $K = Ce^{-a/T}$.

The value, a, multiplied by R in calories gives q, the energy of activation or the "work of loosening" for the given reaction.

Reaction $SiO_2 + Na_2CO_3$ (2:1)

Temp. (°C)	$10^4/T$	Log ($K \times 10^7$)
758	96.99	2.0158
748	97.94	1.7596
728	99.90	1.2479
702	102.56	0.7468

These data lead to

$a = 2.303 \times 0.7679/2.91 \times 10^{-4} = 60{,}770$
$q = 1.988 \times 60{,}770 = 120{,}800$ cal./mol CO_2

The value of C in the above equation is calculated as follows:

Since $K = Ce^{-a/T}$
Log C = log K + 60,770/2.303T
Log $C = \bar{5}.0158 + 60{,}770/2.303 \times 1031$
Log $C = 20.6108$
$C = 4.081 \times 10^{20}$.

The general equation for the velocity of this reaction may be written

$$K = 4.081 \times 10^{20} e^{-60770/T}.$$

VII. Reaction Velocity of $3Al_2O_3{\cdot}2SiO_2 + Na_2CO_3$ (1:3)

The mullite used in these determinations was obtained from J. W. Greig of the Geophysical Laboratory in Washington, D. C. The material was extremely fine so that it was impossible to get a 150- to 200-mesh grain size from the sample; consequently the materials used in these experiments were all screened through a 200-mesh sieve. The mullite and sodium carbonate were weighed out in the molecular ratio of 1 to 3 and then mixed in the usual manner before placing in the desiccator.

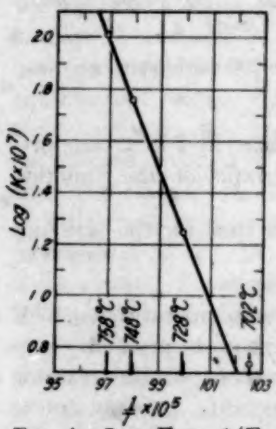

FIG. 4.—Log K *vs.* $1/T$ from data of Fig. 3.

Reaction rates for this mixture were determined at five different temperatures, 608°C, 649°C, 699°C, 724°C, and 756°C. It was found advisable to use a 0.100-gram charge for the reactions above 700°C to get enough readings before the limit of the buret was reached.

Graphs of the function $\left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$ plotted against the time for the three highest temperatures are given in Fig. 5. The amounts of reaction at 608°C were so small that they were not plotted on this graph.

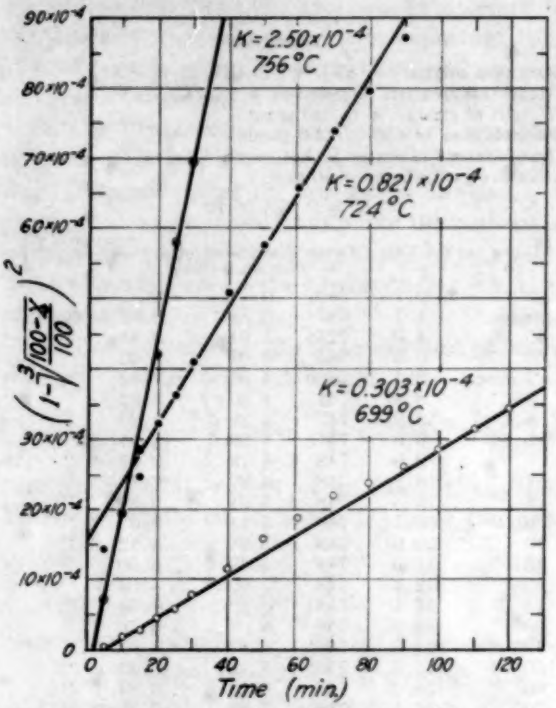

FIG. 5.—Rate data on minus 200-mesh mullite + Na_2CO_3 (1:3).

Figure 6 shows log K *versus* $1/T$ for the above three determinations. The values plotted, together with the derived a, q, and C quantities are given as follows:

Reaction $3Al_2O_3{\cdot}2SiO_2 + Na_2CO_3$ (1:3)

Temp. (°C)	$10^4/T$	Log ($K \times 10^6$)
756	97.18	2.3979
724	100.31	1.9146
699	102.88	1.4810

$a = 37{,}050$
$q = 73{,}650$ cal./mol. CO_2
$C = 1.079 \times 10^{12}$

The three points come very close to falling on a straight line. It was found that log K for the 649°C reaction when plotted does not agree well with the slope shown in Fig. 6, indicating that

the determination at this low temperature is not very accurate.

The general equation for the velocity of this reaction may be written

$$K = 1.079 \times 10^{12} e^{-37,050/T}.$$

VIII. Reaction Velocity of $3Al_2O_3 \cdot 2SiO_2$ + Na_2CO_3 (1:1)

The mullite used in these reactions was that prepared in the laboratory by G. R. Pole. The grain size used in all of the determinations was the material passing through a 150-mesh sieve and remaining on a 200-mesh sieve. The ratio of the mullite to sodium carbonate was changed to a 1 to 1 ratio for these reactions because more of this mullite was available. The materials were weighed out in the above ratio and mixed by stirring with a spatula and sieving through an 80-mesh screen. No determination was made at 600°C because the reaction at 651°C indicated that the velocity would be extremely low at this temperature.

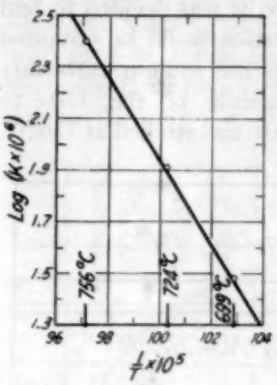

FIG. 6.—Log K vs. $1/T$ from data of Fig. 5.

Figure 7 shows the slopes of the curves for the reactions at 755°C, 723°C, and 704°C when the function $\left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$ is plotted against the time, t.

Figure 8 is a graph of the log K values found in Fig. 7, plotted against the reciprocal of the corresponding absolute temperatures. The values used for this graph together with the calculated a, q, and C quantities are given as follows:

Reaction $3Al_2O_3 \cdot 2SiO_2$ + Na_2CO_3 (1:1)

Temp. (°C)	$10^4/T$	Log ($K \times 10^8$)
755	97.28	2.1316
723	100.40	1.5910
704	102.35	1.2957

a = 38,000
q = 75,550 cal./mol. CO_2
$C = 1.523 \times 10^{12}$.

The general equation for the velocity of this reaction may be written

$$K = 1.523 \times 10^{12} e^{-38,000/T}$$

The heats of activation for the two curves (Fig. 6 and 8) are 73,650 calories for mullite A and 75,550 calories for mullite B. The agreement is probably satisfactory when one considers that in the first case the molecular ratio of mullite to sodium carbonate is 1:3 and in the second case, 1:1. The results show that the energy quantity is independent of particle size of the mullite used.

Samples of the products of reaction between the mullite-sodium carbonate and silica-sodium carbonate were examined with the microscope to identify any new phases. It was found impossible to identify any compounds, but the silica

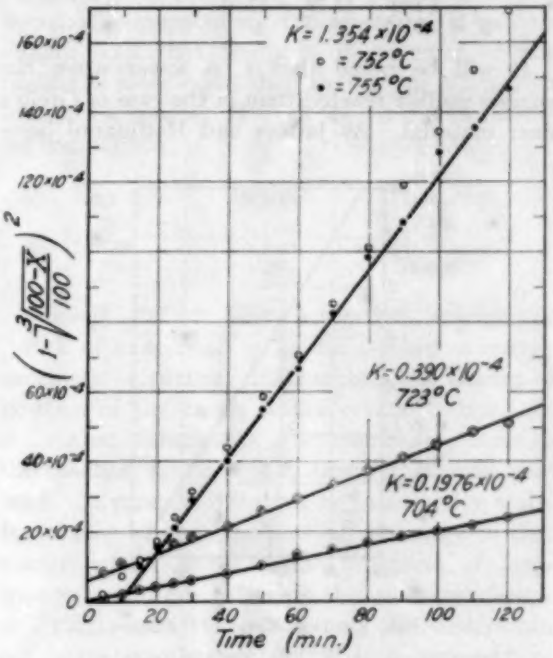

FIG. 7.—Rate data on 150- to 200-mesh mullite + Na_2CO_3 (1:1).

grains showed distinct evidence of attack by the rounded edges, and the index of refraction was lower than 1.545. Each grain appeared to be covered by a thin layer or coating that looked like glass or glaze. The index was determined to be slightly higher than 1.515.

The mullite also showed evidence of reaction by narrow bands of material surrounding the needle-like crystals of mullite. This coating seemed to cut down the birefringence and the index was lower than 1.645.

In the two sets of data on mullite it will be noted that the values of a = 37,050 and 38,000 calories per mol. were obtained. Probably a

mean value of 37,500 may be taken as being closest to the correct quantity. With this value, C is calculated at some one temperature for the reaction of sodium carbonate with the two preparations of mullite.

Greig's mullite, 200-mesh, 765°C, log $K = \bar{4}.398$
Laboratory mullite, 150- to 200-mesh, 755°C, log $K = \bar{4}.132$

For Greig's mullite

$$\text{Log } C = \bar{4}.398 + 37{,}500/2.303 \times 1033$$
$$= \bar{4}.398 + 15.76 = 12.16$$
$$C = 1.45 \times 10^{12}$$

For laboratory mullite

$$\text{Log } C = \bar{4}.132 + 37{,}500/2.303 \times 1032$$
$$= \bar{4}.132 + 15.78 = 11.91$$
$$C = 0.81 \times 10^{12}$$

It will be noted that C is lower when the coarser mullite reacted than in the case of Greig's finer material. As Jander and Hoffmann[7] have pointed out, C is most markedly changed in a given reaction by changing the method of preparation of the components and by the presence of impurities. In fact, the results largely parallel the experience in the behavior of solid catalysts for many reactions.

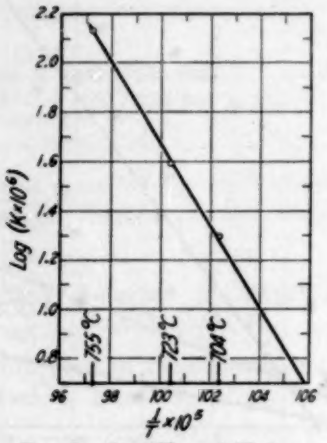

FIG. 8.—Log K *vs.* $1/T$ from data of Fig. 7.

IX. Reaction Velocity of $Al_2O_3 + Na_2CO_3$ (3:1)

The 150- to 200-mesh crystalline α-Al_2O_3 for this reaction was mixed with the sodium carbonate in the molecular ratio of 3 to 1 because that was the ratio it bore to sodium carbonate in the second series of mullite reactions, $3Al_2O_3 \cdot 2SiO_2 + Na_2CO_3$, where the mullite grain size was 150- to 200-mesh. The results of a determination for the above reaction at 757°C are plotted in Fig. 9. The function $\left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$ was not calculated for this reaction because the extent of the reaction was so small that it was felt that the gas evolution might possibly be due to the decomposition of the sodium carbonate. It was decided, therefore, to plot the percentage of reaction directly against the time as shown in Fig. 9.

After obtaining these results on the alumina-sodium carbonate mixture, it was decided to find out how much CO_2 evolution could be obtained at this temperature with the sodium carbonate alone. A 0.100-gram sample of the 150- to 200-mesh sodium carbonate was studied at 750°C.

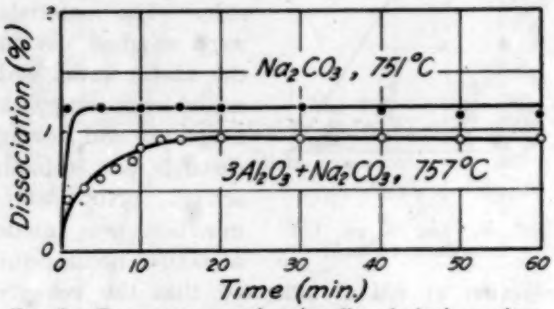

FIG. 9.—Percentage reaction (or dissociation) *vs.* time, Na_2CO_3 series.

The curve of percentage decomposition against the time is also shown in Fig. 9. The curve shows that the decomposition reached a constant value within one minute after the crucible was dropped. The slightly lower equilibrium pressure in the case of the mixture may be due to adsorption of CO_2 on the alumina.

X. Reaction Velocity of $SiO_2 + CaCO_3$ (2:1)

The 150- to 200-mesh SiO_2 and $CaCO_3$ were weighed out in a molecular ratio of 2 to 1 and then thoroughly mixed in the usual manner. The first reaction was run at 595°C using a 0.200-gram sample of the reaction mixture. The percentage reaction was so small that it reached a constant value within one minute after the start. The same reaction was then repeated at 700°C. The percentage reaction *versus* the time was plotted as shown in Fig. 10.

[7] W. Jander and E. Hoffmann, *Z. anorg. allgem. Chem.*, **200**, 249 (1931).

XI. Reaction Velocity $3Al_2O_3{\cdot}2SiO_2 + CaCO_3$ (1:1)

The 150- to 200-mesh laboratory mullite was used for these reactions. The materials were weighed and mixed in the given molecular ratio. The first determination for this reaction was made at 599°C. This reaction was quite slow and reached a maximum value within six minutes after the start. The same reaction was repeated at 698°C with the results shown in Fig. 10.

XII. Reaction Velocity $Al_2O_3 + CaCO_3$ (3:1)

The material, 150- to 200-mesh crystalline α-Al_2O_3 and $CaCO_3$, was weighed in the molecular ratio of 3 to 1 and then thoroughly mixed by screening through an 80-mesh sieve. After obtaining the above results on silica and mullite,

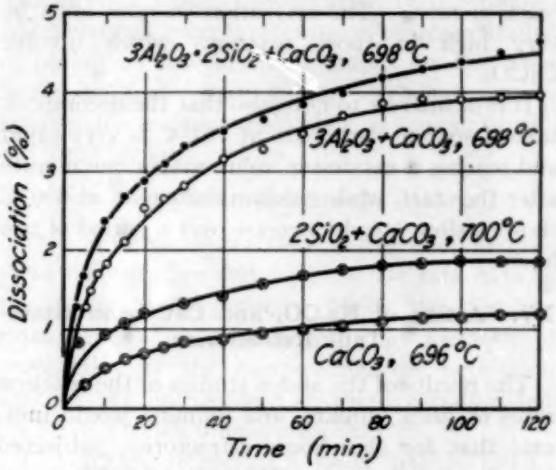

FIG. 10.—Percentage reaction (or dissociation) *vs.* time, $CaCO_3$ series.

it was decided to make the first reaction determination for the above mixture at or near 700°C. A plot of the percentage reaction at 698°C *versus* the time is also shown in Fig. 10.

XIII. Decomposition of $CaCO_3$ at 696°C

After making the above reaction-rate determinations on silica, mullite, and alumina, it was decided to determine the percentage decomposition of the crystalline $CaCO_3$ in order to know how much of the CO_2 was due to reaction and how much due to dissociation of $CaCO_3$ itself. A determination was then made on a 0.200-gram sample of the crystalline $CaCO_3$ at 696°C. The graph of the curve of percentage decomposition against the time is given in Fig. 10.

XIV. Discussion of Data

(1) Reactions Involving Sodium Carbonate

In studying the reaction data of silica and mullite with sodium carbonate for the 150- to 200-mesh grain size, some interesting facts are brought out. The q values, or energies of activation, for these two reactions were 120,800 calories for the quartz and 75,550 calories for the mullite. In other words, it takes about 1.6 times the energy to initiate the silica-sodium carbonate reaction as for the mullite-sodium carbonate reaction, within the temperature range studied. If the K values of these two reactions are compared at corresponding temperatures, it can be clearly seen that the rate of reaction of the mullite is more rapid than that of the silica with sodium carbonate. This is shown in the following comparison:

Temp. (°C)	$K \times 10^4$ Mullite	Quartz
755	1.354	0.104
723	0.390	0.058
704	0.198	0.006

Jander[8] defines the activation energy or "work of loosening," q, as the amount of energy necessary to permit "Platzwechsel" or change of position of the atoms in the crystal lattice. In order that diffusion of a substance, A, through the reaction product, AB, to meet B, may proceed, the product AB must be in an active state. It is believed that the activation energy is that energy which gives atomic vibration of large enough magnitude to permit this atomic exchange or "Platzwechsel." At present, the writers can not state whether or not q is a property of the reactant or of the product. For the self-diffusion of solid lead, it has been shown by Seith and Keil[9] that the energy of activation is 27,870 calories per mol. For the diffusion of other metals such as Ag, Bi, and Sn into Pb, the values are lower because of the lower solubility of these metals in Pb and the correspondingly weaker bonds between Pb and the metal, which have to be broken as the foreign atoms diffuse further into the Pb. In the case of the quartz-sodium carbonate system, the activation energy has been found to be 120,800 calories and in the case of the mullite-sodium carbonate system it is 75,550 calories. These higher values may arise

[8] W. Jander, *Z. anorg. allgem. Chem.*, **163**, 1–30 (1927).
[9] W. Seith and A. Keil, *Z. Metallkunde*, **25**, 104–106 (1933).

because of the firmness of binding between the constituents of sodium silicate on the one hand and possibly of nephelite on the other. It is believed that the energy requirement of diffusion processes is the one chiefly controlling the activation energy which is found from the kinetic data.

If these same reactions are compared with the alumina-sodium carbonate reaction at 757°C given in Fig. 9, the amount of the latter reaction will be seen to be considerably less than that for either the silica or the mullite. The percentage of reaction Na_2CO_3 with Al_2O_3 after two hours at 757°C is about the same as that for silica and sodium carbonate at 646°C. When reaction rates become so small it is difficult to measure them accurately, and in some cases any absorption of moisture or gases would cause a big error in their determination. Since no other determinations were made on the alumina-sodium carbonate reaction, its energy of activation can not be calculated, but the slow rate at 757°C would lead one to believe that the value would be much greater than that for the silica-sodium carbonate reaction. A study of the decomposition of sodium carbonate at 751°C, as shown in Fig. 9, would indicate that the amount of reaction between alumina and sodium carbonate was extremely small, if any at all, because the percentage decomposition exceeds the apparent percentage of reaction.

(2) Reactions Involving Calcium Carbonate

The remaining experiments on the reaction rates between silica, alumina, and mullite with calcium carbonate are of a more or less negative nature but, in spite of this, the results have real significance. In most cases the reaction rates were so low that it was not possible to get enough data to determine the K values at different temperatures so that the results were plotted as shown in Fig. 10. It was not thought advisable to go above 700°C with the $CaCO_3$ since the decomposition pressure rises rapidly from this temperature.

The reaction rates of silica with calcium carbonate at 595°C reached a constant value within one minute after the start. The percentage reaction was so small that the values obtained would indicate little if any interaction. The mullite-calcium carbonate reaction at 599°C reached a constant value within six minutes after the beginning of the experiment and the percentage of reaction was approximately twice that obtained with silica.

The results of the silica, alumina, and mullite reactions with calcium carbonate near 700°C are shown in Fig. 10, where the percentage reaction is plotted against the time. The decomposition of $CaCO_3$ is also plotted with these curves to bring out the fact that some reaction does occur. The mullite shows the largest percentage reaction after two hours, followed by alumina, and finally by silica which shows the slowest rate. It is believed that the differences are great enough to demonstrate the relative behavior of these materials when mixed with calcium carbonate at this temperature. The reaction of calcium carbonate in all cases is much less than that obtained with sodium carbonate and it is interesting to note that in both cases the mullite gave the highest reaction rates. The activation energies must be very high in those reactions which involve $CaCO_3$.

It is of interest to note also that the decomposition of sodium carbonate at 751°C is very rapid and reaches a maximum value within one minute after the start, while calcium carbonate at 696°C shows a slow, steady increase over a period of two hours.

XV. Action of Na_2CO_3 and $CaCO_3$ on Glass-Tank Refractories

The results of the above studies of the reaction rates of silica, mullite, and alumina would indicate that for glass-house refractories, subjected to sodium carbonate or Na_2O dusts and fumes, a refractory with a large amount of free corundum present would be preferable to a mullite refractory, provided they had the same porosity and body structure. Of course, there is the possibility that at higher temperatures other factors might influence these reactions so that the differences in reaction rates would not be as great. It is a well-known fact, however, that large aggregates of corundum crystals can be found on the surfaces of fireclay refractories above the "metal" line in glass tanks. It has also been found in the last few years that dense refractories with a high percentage of crystalline alumina have given satisfactory service in glass tanks above the liquid surface. Silica brick have also given good service above the "metal" line of the glass tank and if means could be found to decrease their porosity, a longer life should be expected.

If the measurements involving $CaCO_3$ can be taken as an indication of behavior in chemical attack by $CaCO_3$ or CaO dusts on glass refractories above the glass line, silica would show the least attack followed by alumina and mullite. Whether this is of any significance will have to be proved by further study.

It should be borne in mind that intimate contact was a prerequisite in the experiments described. In commercial refractories of low permeability, the poor contact between corrosive dust and refractory may give protection for long periods.

In regard to the relative attack on silica by sodium carbonate and by calcium carbonate, the results of this investigation are in essential harmony with those of Turner[10] who has studied the chemical processes underlying glassmelting. Turner reports that calcium carbonate decomposes completely at lower temperatures than are needed to permit its reaction with silica. On the other hand, he finds that sodium carbonate shows appreciable reaction with silica as low as 646°C.

XVI. Summary

(1) Solid-phase reactions, which evolve a gas, yield quantitative and reproducible rate data in the apparatus described. While the absolute rates depend on particle size and methods of preparation of the components, the activation energies are independent of these variables but are related to the diffusion mechanism.

(2) In the temperature range 700° to 750°C, sodium carbonate reacts most rapidly with mullite, less rapidly with quartz, and least rapidly with corundum when the latter have equal particle size. The activation energy of the sodium carbonate-quartz reaction is approximately 60% greater than that for the sodium carbonate-mullite reaction (120,800 calories as compared with 74,600 per mol CO_2).

(3) Calcium carbonate shows a much lower rate of reaction with mullite, quartz, and corundum than does sodium carbonate at corresponding temperatures. It reacts most rapidly with mullite, less with corundum, and least with quartz.

(4) Changes in refractive index were observed in the reaction products, but no identification was made.

(5) The results of the investigation have direct bearing on the mechanism of the glass-melting process and are in agreement with the observations of Turner.[10] They also suggest an explanation of the behavior of certain glass-house refractories when exposed to vapors and dusts encountered in glassmelting.

(6) In the preparation of mullite by heating mixtures of cristobalite and alumina plus a small amount of lime as a flux, the best results are obtained by using batches that lie in the composition triangle mullite, anorthite, and silica. The alumina should be of an amorphous type to permit rapid solution and to obtain a product free from corundum.

(7) A table of values of the function, $F = \left(1 - \sqrt[3]{\frac{100 - x}{100}}\right)^2$, for positive integral values of x from 1 to 100 is given as Table I.

Acknowledgments

The suggestions of J. W. Greig of the Geophysical Laboratory, Washington, D. C., were of material help in the preparation of pure mullite. The authors are indebted to F. J. Williams for assistance in constructing the apparatus as well as for his X-ray work on mullite.

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[10] W. E. S. Turner, "Recent Studies of the Fundamental Processes Underlying Glassmelting," *Jour. Amer. Ceram. Soc.*, **17** [2] 21 (1934).

INVESTIGATION OF THE USE OF MAGNESIUM ALUMINATE (SPINEL) AS A MATERIAL FOR GLASSMELTING CONTAINERS*

By C. W. Parmelee and K. C. Lyon

Abstract

Crucibles were formed from spinel raw materials and commercial spinel grains, with and without admixtures of other chemicals. Bottle glass was melted in these and the behavior was compared with similar containers made from fireclay grog and mullite (Corhart).

The tests consisted of heating bottle glass in the crucibles at 1400°C for four hours and noting the appearance of the crucibles after the treatment. The results indicated that, under the conditions used, magnesia spinel is not suited for glass refractory material.

I. Introduction

Since the chief cause of the chemical failure of refractories in contact with glass melts is considered to be the action of the alkali and alkaline earth oxides upon them, the use of a neutral refractory, namely magnesia spinel, is very alluring. In this investigation, a comparison has also been made of the relative resistance of containers made from MgO and Al_2O_3, mullite, and fireclay grog.

(1) Literature

A survey of the literature disclosed only a few reports,[1] each indicating that spinel is resistant to the attack of silicate melts of the nature of ordinary glasses, slags, mill scale, and coal ash. An examination of the equilibria diagrams which applied to the MgO–Al_2O_3–SiO_2 system was not helpful because of the complexity of the melts used, the physical structure of the crucibles, and the lack of information regarding the physical characteristics of the melts, particularly viscosity and surface tension.

II. Experimental procedure

Other investigators[2] have discussed the preparation of spinel by heating a mixture of magnesium and aluminum oxides with a small admixture of boric oxide. The spinel used in the first part of this investigation was made from magnesia and alumina of C.P. quality in a molecular ratio of 1:1 with 5% admixture of B_2O_3 added as H_3BO_3. This powdered material was ground dry in a ball mill for two hours, moistened with saturated dextrine solution, and dry-pressed into blocks. These blocks, 2 by 2 by 1 inch, were fired in a gas furnace to 1300°C, the maximum temperature being maintained for several hours. The linear firing shrinkage was found to be 12%. X-ray examination of the material showed the absence of MgO and Al_2O_3.

In order to provide a standard material for purposes of comparison, grog was prepared from St. Louis fire clay by washing the weathered clay and calcining at cone 10.

The Corhart Refractories Company, Inc., supplied a quantity of 12-mesh mullite material which had been treated to remove free iron.

Brick, formed from bonded, electrically fused spinel, were used as an additional source of that material.

These four materials were ground separately in porcelain ball mills after being suitably crushed and passed over an electromagnet to remove free iron. The sieve analyses of the ground materials were as follows:

Sieve No.	Per cent by weight retained				Size of opening (mm.)
	Spinel*	Grog†	Mullite**	V. spinel‡	
40	0	0	0	0	0.424
60	3	15	18.5	19	.247
80	1.5	7	10.5	9	.173
100	0.5	5	7.5	7	.140
150	0.5	5	6	3	.091
200	5.0	13	15	12.5	.084

* Spinel, $MgO{\cdot}Al_2O_3$ prepared in laboratory.
† Grog, St. Louis fireclay grog.
** Mullite, received from the Corhart Company; the mullite used in these tests was pulverized material which was formed into shape and bonded by heating; it should not be confused with the Corhart regular product formed by casting the melt.
‡ V. spinel, from brick made by the Vitrefrax Company.

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (Refractories Division).

[1] (*a*) J. A. Cunliffe and H. E. Clem, "Refractories for Use in Sulfate-Recovery Furnaces of the Pulp and Paper Industries," *Jour. Amer. Ceram. Soc.*, **15** [6] 321–33 (1932).
(*b*) E. Kothny, "Refractory Materials for the Electric Steel Furnace," *Feuerfest*, **3** [10] 157–64 (1927); *Ceram. Abs.*, **7** [5] 295 (1928).
(*c*) F. H. Norton, Refractories, New York, 1931, p. 378.
(*d*) Ceramic Products Cyclopedia, 5th ed., Chicago, 1930, p. 396.
(*e*) A. Jaeschke, "Influence of Molten Glass on Refractory Materials," *Feuerungstechnik*, **3** [3] 19–20 (1927); *Trans. Ceram. Soc.* [Eng.] **26**, 65*A* (1926–27); *Ceram. Abs.*, **10** [7] 288 (1927).

[2] (*a*) C. W. Parmelee, A. E. Badger, G. A. Ballam, *Univ. of Ill. Bull.*, No. 29, 84 (1932).
(*b*) R. Rieke and K. Blicke, "Development, Properties, and Technical Use of Some Spinels," *Ber. deut. keram. Ges.*, **12** [4] 163 (1931); *Ceram. Abs.*, **10** [10] 704 (1931).

It can be seen at once that the proportions of the sizes of the different materials were poorly allotted for the best results in packing. Most of the spinel made in the laboratory passed through the 200-mesh sieve. It was considered that the method of formation was such that the individual crystals were not permitted to grow or to form aggregates of appreciable size.

The various powdered materials were moistened with a saturated dextrine solution and were pressed into cylinders, $^7/_8$ inch in diameter and about $1^1/_4$ inch in length, in a steel mold under a pressure of 10,000 pounds per square inch, thirty seconds being allowed for formation. After drying, the volumes of the test pieces were determined by use of a mercury displacement volumeter.

The test pieces were fired in a gas furnace to 1050°C, 1200°C, 1300°C, and 1350°C, respectively, the maximum temperatures being held for two hours in each case. After cooling, their volumes were again determined. The crushing strengths of the test pieces were also determined as a measure of the bond developed in the firing.

Firing temp. (°C)	Volume shrinkage (%)				Compressive strength (lb./in.²)			
	Grog	Mullite	Spinel	V. spinel	Grog	Mullite	Spinel	V. spinel
1050	−3.1	2.2	−1.9	1.6	1500	2320	9000	0
1200	3.3	2.9	0.0	2.1	2200	12300	6400	700
1300	7.5	3.0	4.7	3.0	4400	7800	2200	1700
1350	17.4	2.8	10.4	8.7	8900	10300	2200	1700

It was observed that the spinel cylinders were cracked on the surface in many cases; the "V. spinel" cylinders were soft and crumbled on the edges.

It was thought best to proceed at once with the testing of glass corrosion resistance before attempting any further work on grain sizing and firing procedure. The trial pieces for the glass-corrosion tests were small crucibles made in a cylindrical steel mold, $^7/_8$ inch in diameter. The inside was shaped by attaching a stud to the upper plunger of the mold used in the preparation of the test cylinders of the earlier part of the work. This stud was designed to give the crucible a wall thickness of $^1/_8$ inch at the top and $^1/_4$ inch at the bottom, the depth being 1 inch. The four test materials used were moistened with dextrine solution and were packed in the mold by hand, care being taken to insure that the material was around the stud. A pressure of 10,000 pounds per square inch was used in forming the crucibles. These were then dried, some being fired to 1350°C for two hours and others to 1550°C for the same length of time.

The porosities of the test crucibles were found by saturation with kerosene *in vacuo*.

Firing temperature (°C)	Porosity (%)			
	Grog	Mullite	Spinel	V. spinel
1350	29	28	40	32
1550		28	37	27

One crucible of each type of those fired to 1350°C was filled with bottle-glass cullet of the following composition:

	Bottle-glass cullet (%)		Bottle-glass cullet (%)
SiO_2	74.15	MgO	3.67
Al_2O_3	0.65	Na_2O	15.25
Fe_2O_3	0.04	BaO	0.35
CaO	5.50	As, Sr, Se, Co	Trace

The crucibles and their contents were heated to 1400°C and held at that temperature for four hours. When they were examined after cooling, it was found that the glass apparently had seeped through those made from the spinel, leaving behind a badly pitted, vesicular structure in the crucible. X-ray examination of the material failed to show any crystalline change. The mullite showed less attack and penetration than the spinel and the grog still less, although the glass in the clay crucible was colored a dark green and a mullite and corundum interface (determined microscopically) existed between the glass and the refractory body.

The results from similar tests of crucibles fired at 1550°C were no different from those with the crucibles fired at the lower temperature.

To test the permeability of the crucibles, a set, one of each composition, after being fired to 1550°C, was filled with distilled water at room temperature. The results were as follows:

Material	Time required to empty (by seepage through crucible wall)
Grog	More than one hour
Mullite	11 min., 10 sec.
Spinel	24 " 10 "
V. spinel	17 " 49 "

The leakage of glass from the spinel crucibles could not be explained solely on the basis of permeability, since the mullite crucibles were more permeable to water and yet retained the glass melt better.

Since the failure of the spinel crucibles might be attributed to poor bonding, several more

experimental compositions were prepared as follows:

(1) V. spinel, 70% 20- to 40-mesh, 30% 150- to 200-mesh with admixtures of feldspar, fluorspar, and forsterite.
(2) MgO and Al_2O_3 in 1:1 molecular ratio with B_2O_3 admixture.
(3) MgO and Al_2O_3 in 1:1 molecular ratio with admixtures of feldspar, fluorspar, and forsterite.
(4) Same as (3) with additional admixture of B_2O_3.

The admixtures were made in amounts up to 5% by weight.

The forsterite was prepared by heating MgO and SiO_2 in molecular ratio of 2:1 in an electric arc. The solid material so formed was pulverized before being added to the batch.

The crucibles, formed by use of the procedure outlined above, were fired at 1550°C for two hours and, after cooling, their porosities were determined by saturation with kerosene. The results show that, with the amounts used, fluorspar is most effective in reducing porosity with feldspar and forsterite about equivalent in action.

The test with glass cullet at 1400°C for four hours showed no noticeable improvement in conduct.

III. Discussion of Results

On the basis of the tests outlined above, it would seem that magnesia spinel is unsuited for fabrication of glass refractories. The tests have failed to show whether the difficulty lies in a failure to produce a satisfactory bond or in chemical weaknesses. Comparing the tests of water permeability with the behavior of molten glass, it might seem that the products formed from the reaction of spinel and glass are not sufficiently viscous to prevent the flow of the molten glass through the crucible pores. The presence of magnesia in the crucible composition may account for an assumed decrease of viscosity of the glass since magnesia does increase fluidity of glasses at high temperatures.

The matter of bond in spinel brick has been a stumbling block in the path of their successful application. A solution of the problem seems to be in the manufacture of products by casting in the molten state, such as is being used in making cast mullite blocks. This, of course, would require the use of very high temperatures and a specialized technique.

Acknowledgment

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THE DETERMINATION OF ALKALIS IN SILICATES WITH SPECIAL REFERENCE TO HIGH-ALUMINA REFRACTORIES*

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Abstract

This investigation pertains to the detailed study of two methods used to determine alkalis in silicates. The work was prompted through the difficulty of obtaining complete decomposition of high-alumina refractory materials by the usual procedure.

It was found that high-alumina materials may be decomposed by the J. Lawrence Smith procedure with a single fusion, provided this is conducted at approximately 1200°C.

The second procedure has to do with the decomposition of the sample with a mixture of nitric, sulfuric, and hydrofluoric acids. In this method, magnesia is eliminated by precipitation with 8-hydroxyquinoline and the alkalis are weighed as sulfates. Experimental data are given pertaining to these procedures when used for the analysis of several types of materials.

I. Introduction

With silicate materials, an accurate determination of the alkali content is more difficult than that of the other elements, particularly so in the case of high-alumina refractories. Analyses of identical samples by several commercial laboratories have shown extremely wide variations in the values for the alkalis. The J. Lawrence Smith method is most widely used for these determinations.

The work described here was prompted by the inability to obtain complete decomposition of high-alumina refractory materials by a single fusion when using this procedure. In routine analysis, it is essential that complete decomposition be accomplished without more than one fusion.

Two methods for the determination of alkalis in silicates were investigated. In addition to the J. Lawrence Smith method, a procedure will be discussed which depends on the decomposition of the silicates by a mixture of hydrofluoric, nitric, and sulfuric acids.

II. The J. Lawrence Smith Method

There is very little information on the proper temperature for fusing the sample with the mixture of ammonium chloride and calcium carbonate. Experiments showed that if the preliminary heating was conducted at 600°C, the ammonia was eliminated with no loss of chloride, while at 700°C, 3% of the chloride present was volatilized. Furthermore, it was found that, while a feldspar could be completely decomposed by a single fusion at a red heat (about 800°C), the full temperature of a blast burner was needed to obtain complete decomposition of a sample of cast refractory containing 75% Al_2O_3.

When a sample of feldspar was mixed with NH_4Cl and $CaCO_3$, placed in an ordinary platinum crucible, and the ammonia eliminated by heating at 600°C, a final heating for 2 hours over a blast burner resulted in complete volatilization of the alkalis. This indicated the necessity for adequate cooling of the top of the crucible during fusion to prevent the loss of alkalis by vaporization.

(1) Furnace Devised

A small furnace was constructed, consisting of a $4^1/_2$-inch nichrome heating unit, set in a vertical position and surrounded by high-temperature insulating material. The temperature of the furnace was controlled by means of an autotransformer and rheostat. Figure 1 shows this furnace with the crucible in position for heating.

The crucibles in which the fusions were conducted were of the J. Lawrence Smith type, but were 10 centimeters long instead of the usual 8-centimeter length. The additional 2 centimeters was to insure satisfactory cooling of the upper part of the crucible to prevent any loss of alkali by volatilization. Nickel crucibles may be used, but their short life makes them much more expensive than platinum.

The nichrome heating element is not recommended for use at temperatures much over 1000°C, but it was found that as many as 80 heatings at 1200°C could be made before the element failed.

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III. Treatment of Samples to Determine the Effect of Fusion Temperature on the Decomposition of Silicates by the J. L. Smith Method

A 0.5000-gram sample was ground as fine as possible in an agate mortar; 0.500 gram of NH_4Cl was added and the grinding was continued until the two were intimately mixed; 3 grams of special reprecipitated $CaCO_3$ were added and thoroughly mixed by grinding. After placing 1 gram of $CaCO_3$ in the bottom of the crucible, the mixture containing the sample was transferred to the crucible. Any sample adhering to the mortar or pestle was recovered by grinding with 1 gram $CaCO_3$. This was transferred to the crucible, and finally a layer of 1 gram $CaCO_3$ was placed on top. The crucible was tapped gently to cause the charge to settle.

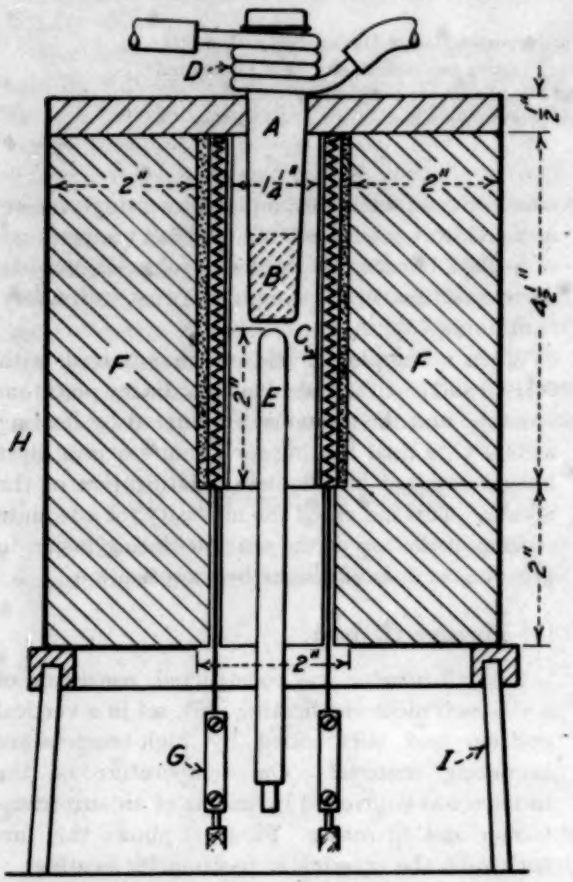

FIG. 1.—*A*, J. Lawrence Smith crucible; *B*, charge; *C*, nichrome heating unit; *D*, 3/16-in. copper tubing for water-cooling system; *E*, thermocouple protection tube; *F*, refractory insulation; *G*, heating element leads to transformer; *H*, galvanized-iron jacket; *I*, furnace support.

The crucible was then set in the hole in the cover of the furnace with the cooling coil of copper tubing around the top of the crucible. The hole in the cover was of such size as to allow the lower half of the crucible to extend into the furnace.

With the crucible uncovered, the furnace was heated to 600°C and held at that temperature until all of the ammonia was expelled. With the crucible lid in place and a stream of water flowing through the cooling coil, the temperature was increased to the particular point desired, and this temperature was held constant for 30 to 40 minutes.

The crucible was removed and, when cool, the sintered cake was removed, leached with water, filtered, and washed in the usual manner. The alkali chlorides were determined in the filtrate by the usual procedure.

To ascertain if decomposition had been complete, a determination of the alkali chlorides was made on the insoluble residue. After drying, the residue was removed from the paper, mixed by grinding with 0.500 gram NH_4Cl, and heated again. This time the fusion was conducted at 1200°C.

Table I shows the results obtained in the experimental analyses conducted. In this work no attempt was made to separate the soda and potash since the purpose was merely to determine the temperature required for complete decomposition of the samples by a single fusion.

IV. Observations on the J. Lawrence Smith Method

The preliminary heating to expel the ammonia should be conducted at not over 600°C.

Although the data are not complete enough to draw definite conclusions, indications are that the temperature necessary for decomposition is dependent upon the alumina content of the sample, with the high-alumina materials requiring a fusion at 1200°C to obtain complete decomposition.

During the fusion of the samples, the upper portion of the crucible should be cooled to prevent loss of alkalis by vaporization.

V. The Hydrofluoric-Acid Method

Some silicates, notably feldspars, clays, ganister rock, silica refractories, and some fired fireclay refractories, may be decomposed by treatment

with a mixture of hydrofluoric, nitric, and sulfuric acids. Subsequent to this treatment, it is possible to determine the alkalis after the elimination of the other elements. By the use of the method outlined below, not only the alkalis may be determined, but also CaO, MgO, Al_2O_3, Fe_2O_3, TiO_2, etc., on the same sample.

TABLE I

EFFECT OF TEMPERATURE OF FUSION IN J. LAWRENCE SMITH METHOD FOR ALKALI DETERMINATION

Sample	Temp. of 1st fusion (°C)	Weight of alkali chlorides present* (gram)	Weight of alkali chlorides found after 1st fusion (gram)	Error	Weight of alkali chlorides found after 2nd fusion (gram)	Total weight of alkali chlorides found (gram)	Error
Bur. Stand. standard sample of feldspar No. 70	800	0.1220	0.1220	0.0000	Nil	0.1220	0.0000
			.1212	− .0008	"	.1212	− .0008
			.1216	− .0004	"	.1216	− .0004
			.1208	− .0012	"	.1208	− .0012
Bur. Stand. standard sample of burnt refractory No. 76 (40% Al_2O_3)	800	.0144	.0086	− .0058	0.0056	.0142	− .0002
			.0094	− .0050	.0050	.0144	.0000
			.0093	− .0051	.0052	.0145	+ .0001
			.0098	− .0046	.0049	.0147	+ .0003
	900	.0144	.0120	− .0024	.0026	.0146	+ .0002
			.0118	− .0026	.0025	.0143	− .0001
			.0120	− .0024	.0028	.0148	+ .0004
			.0124	− .0020	.0022	.0146	+ .0002
	1000	.0144	.0144	.0000	Nil	.0144	.0000
			.0148	+ .0004	"	.0148	+ .0004
			.0146	+ .0002	"	.0146	+ .0002
			.0145	+ .0001	.0002	.0147	+ .0003
	1200	.0144	.0144	.0000	Nil	.0144	.0000
			.0146	+ .0002	"	.0146	+ .0002
			.0144	.0000	"	.0144	.0000
			.0148	+ .0004	"	.0148	+ .0004
			†.0132	− .0012	"	.0132	− .0012
			†.0125	− .0019	"	.0125	− .0019
			†.0126	− .0018	"	.0126	− .0018
			†.0126	− .0018	"	.0126	− .0018
Bur. Stand. standard sample of burnt refractory No. 78 (70% Al_2O_3)	1000	.0274	.0226	− .0048	0.0050	.0276	+ .0002
			.0216	− .0058	.0054	.0270	− .0004
			.0221	− .0053	.0057	.0278	+ .0004
			.0221	− .0053	.0054	.0275	+ .0001
	1100	.0274	.0259	− .0015	.0020	.0279	+ .0005
			.0250	− .0024	.0024	.0274	.0000
			.0253	− .0021	.0022	.0275	+ .0001
			.0256	− .0018	.0019	.0275	+ .0001
	1200	.0274	.0278	+ .0004	Nil	.0278	+ .0004
			.0274	.0000	"	.0274	.0000
			.0276	+ .0002	"	.0276	+ .0002
			.0276	+ .0002	"	.0276	+ .0002
			†.0254	− .0020	"	.0254	− .0020
			†.0260	− .0014	"	.0260	− .0014
			†.0258	− .0016	"	.0258	− .0016
			†.0258	− .0016	"	.0258	− .0016
No. 5679 Sample of cast refractory (75% Al_2O_3)	1000		.0020		0.0020	.0040	
	1000		.0022		.0017	.0039	
	1100		.0030		.0009	.0039	
	1100		.0030		.0010	.0040	
	1200		.0038		Nil	.0038	
	1200		.0041		"	.0041	

* Bureau of Standards figures for K_2O and Na_2O were calculated to KCl and NaCl and the sum of these taken as the weight of alkali chlorides present.

† During the fusion of these samples, the top of the crucible was not cooled.

(1) Procedure

After grinding as fine as possible, place a 0.5000-gram sample in a 50-milliliter platinum dish; moisten with a little water, add 2 ml. nitric acid, 2 ml. sulfuric acid, and 15 to 25 ml. hydrofluoric acid. Evaporate carefully on the warm pad to fumes of SO_3; then place on the hot plate

until no more fumes are observed. Cool, treat a second time with HF, HNO_3, and H_2SO_4, evaporate, and heat as before. Cool, wash down the sides of the dish with 2 ml. sulfuric acid, and again drive off the SO_3.

After cooling, add 15 ml. hydrochloric acid, cover with a watch glass, set on the warm pad, and allow to simmer for 15 minutes. Cool and, with the aid of a rubber policeman and a stream of water, transfer to a 400-ml. beaker.

Dilute to 150-ml. volume with water, boil 5 minutes, and precipitate the Al_2O_3, Fe_2O_3, etc., with NH_4OH, using methyl red as the indicator. Boil 1 to 2 minutes, filter, and wash three times with hot 1% NH_4Cl solution. Reserve the filtrate. Place the paper containing the precipitate in the original beaker, add 10 ml. HCl and macerate with a stirring rod. Add 125 ml. hot water and warm until the precipitate is in solution. Heat to boiling, precipitate, filter, and wash as before. The precipitate may be reserved for the determination of Al_2O_3, Fe_2O_3, TiO_2, etc.

To the combined filtrates in a 400-ml. beaker, add 40 ml. HNO_3, cover with a watch glass supported by a glass triangle, and evaporate carefully to dryness. (The addition of nitric acid is to eliminate the ammonium chloride.) Take up the residue in 25 ml. water and 5 ml. HCl (1 to 1). To recover any R_2O_3 present, precipitate once more with ammonia and filter, catching the filtrate in a 250-ml. beaker. Wash 5 times with hot water.

Evaporate the filtrate to a 50-ml. volume, add ammonium oxalate crystals (sufficient to precipitate the CaO present), cover the beaker with a watch glass, and heat to boiling. Set on a warm pad for one hour, make just ammoniacal, and cool. Filter off the calcium oxalate precipitate, catching the filtrate in a 250-ml. beaker. Wash 6 or 7 times with water.

Heat the filtrate, the volume of which should not be over 100 ml., to 75°C, add 10 ml. 8-hydroxyquinoline solution[1] and 6 ml. NH_4OH, and stir for 5 minutes. After the precipitate settles, filter through a Whatman No. 40 paper or similar paper and wash thoroughly with hot (1 to 40) NH_4OH solution. Reserve the filtrate in a 250-ml. Pyrex-brand beaker for the determination of alkalis. If desired, the precipitate may be dissolved in hot dilute (1 to 10) HCl solution and, after destroying the organic matter with H_2SO_4 and HNO_3, the magnesia may be determined as $MgNH_4PO_4$ in the usual manner.

Evaporate the filtrate from the magnesium oxyquinolate precipitate to dryness. Add 2 ml. H_2SO_4 and 2 ml. HNO_3, cover the beaker with a watch glass, set on the warm pad, and evaporate to fumes of SO_3. Cool, remove the watch glass after carefully washing with a stream of water, wash down the sides of the beaker, and evaporate carefully to drive off the H_2SO_4. Finally heat over a Méker-type burner until no fumes are visible. Cool on an asbestos pad.

Take up the salts in a few milliliters of water and filter through a 7-cm. Whatman No. 42 or similar paper, catching the filtrate in a 50-ml. platinum dish. Wash the paper several times with water, using as little as possible for each washing. To the filtrate in the platinum dish, add 2 drops H_2SO_4, evaporate to dryness, and heat over a burner at a red heat (under 800°C) until no more fumes are observed. Cool, moisten with a saturated solution of $(NH_4)_2CO_3$, (to insure conversion to the normal sulfate salts), and evaporate on a water bath or double pad. When dry, cover the dish with a platinum lid or fused quartz watch glass and heat very carefully, first on the hot plate and then over a low flame, until decrepitation has stopped. Remove the cover and heat over a Méker-type burner until the salts just start to fuse. Cool in the desiccator and weigh. Dissolve the sulfates in a little hot water and filter through a 9-cm. No. 42 Whatman or similar paper, catching the solution in a 250-ml. beaker. Wash well with hot water. Place the filter paper in the platinum dish, ignite, and weigh. The difference in weight is the weight of K_2SO_4 and Na_2SO_4.

To the solution in the beaker add 1 ml. (1 to 4) HCl solution and heat to boiling. To the boiling solution, add drop by drop an excess of 10% $BaCl_2$ solution, and continue boiling 5 minutes. Set on the warm pad for a half-hour, remove, and cool. Filter off the $BaSO_4$ precipitate on a close filter paper, wash twice with dilute HCl solution, and then 5 times with cold water.

[1] The 8-hydroxyquinoline solution is prepared as described by J. C. Redmond and H. A. Bright, "Determination of Magnesium in Portland Cement and Similar Materials by the Use of 8-Hydroxyquinoline." *Bur. Stand. Jour. Research*, **6** [1] 113–20 (1931); R. P. 265. Acetic acid solution of 8-hydroxyquinoline (1.25%): dissolve 25 g. of 8-hydroxyquinoline in 60 ml. of glacial acetic acid. When solution is complete, dilute to a volume of 2 liters with cold water. One milliliter of this solution is equivalent to 0.0016 gram MgO.

Ignite in a clay or porcelain crucible and weigh as $BaSO_4$. The weight of $BaSO_4$ multiplied by 0.34298 gives the weight of SO_3.

Subtract the weight of SO_3 from the weight of the combined alkali sulfates to obtain the weight of (K_2O + Na_2O).

The weight in grams of (K_2O + Na_2O) multiplied by 200 gives the percentage of combined alkalis in the sample.

TABLE II

RESULTS OBTAINED IN THE DETERMINATION OF ALKALIS BY THE HF METHOD

Bur. Stand. standard sample	Total alkalis present (%)*	Total alkalis found (%)	Error (per cent of sample)
Feldspar No. 70	14.96	15.20	+0.24
		14.94	− .02
		15.10	+ .14
		15.06	+ .12
Burnt refractory No. 76 (40% Al_2O_3)	1.75	1.88	+ .13
		1.83	+ .08
		1.82	+ .07
		1.82	+ .07
Burnt refractory No. 77 (60% Al_2O_3)	2.97	2.84	− .13
		2.80	− .17
		2.84	− .13
		2.82	− .15
Burnt refractory No. 78 (70% Al_2O_3)	3.36	3.28	− .08
		3.25	− .11
		3.26	− .10
		3.26	− .10
Clay No. 97	0.87	0.92	+ .05
		0.94	+ .07
		0.88	+ .01
		0.88	+ .01
Clay No. 98	3.45	3.44	− .01
		3.44	− .01
		3.40	− .05
		3.48	+ .03
Silica brick No. 102†	0.36	0.36	.00
		0.36	.00
		0.35	− .01
		0.37	+ .01

* Taken from the recommended values for K_2O and Na_2O in the Bureau of Standards Certificates of Analysis.
† 5.0000 grams used for the determination of alkalis on this sample.

Table II is a tabulation of the results obtained when using the above method for the determination of alkalis on several types of materials.

In the analysis of Bureau of Standards samples Nos. 77 and 78, it was found that considerable material remained insoluble in hydrochloric acid after treatment with the mixture of hydrofluoric, sulfuric, and nitric acids. Sample No. 78 showed the greater amount of insoluble material.

To ascertain how much alkali remained in the insoluble portion, ten 0.5000-gram samples of sample No. 78 were treated with the mixture of hydrofluoric, sulfuric, and nitric acids as described above. After treating with hydrochloric acid, the insoluble material was filtered off, and after washing thoroughly with water, the sample was ignited and weighed. The alkalis in the hydrochloric-acid solution of each sample were determined.

The insoluble residues from the several samples were combined, mixed well, and an analysis of the material made. The alkalis were determined by the J. Lawrence Smith method, the fusions being conducted at 1200°C to insure complete decomposition. Table III shows the data obtained.

TABLE III

ALKALIS RECOVERED FROM PORTION OF SAMPLE NO. 78 SOLUBLE IN HYDROCHLORIC ACID, AND ANALYSIS OF INSOLUBLE MATERIAL

Sample No.	Weight of insoluble residue (gram)	Alkalis found in HCl solution (%)	Alkalis present (Bur. Stand. figures)	Analysis of insoluble residue (%)	
1	0.2686	3.28			
2	.2694	3.26		SiO_2	1.10
3	.2690	3.26		Fe_2O_3	0.38
4	.2682	3.26		TiO_2	0.43
5	.2694	3.28		CaO	0.04
6	.2688	3.26	3.36	MgO	0.08
7	.2650	3.28		Alkalis (K_2O + Na_2O)	0.09
8	.2644	3.26			
9	.2648	3.26		Al_2O_3, not determined	
10	.2662	3.24			

VI. Observations on the Hydrofluoric-Acid Method

The hydrofluoric-acid method gives satisfactory results for samples which are completely decomposed by the mixture of hydrofluoric, sulfuric, and nitric acids.

This procedure is especially suited to the determination of alkalis in fire clays and silica materials. In the analysis of silica refractories, it is possible to use 5- to 10-gram samples for the determination of the alkalis, thus insuring results which are extremely accurate.

With high-alumina materials, there is a tendency to obtain slightly low results due to incomplete decomposition of the sample. It was demonstrated, however, that although more than half the original sample of Bureau of Standards sample No. 78 was insoluble after the treatment with hydrofluoric acid, only 0.5 milligram of alkali was retained in the insoluble portion.

The method possesses the advantage of the direct determination of total alkali content without the necessity of separation of K_2O and Na_2O.

VII. General Conclusions

For precise analysis of high-alumina materials, the J. Lawrence Smith method is preferable to the hydrofluoric-acid method, provided the fusion temperature is high enough to insure complete decomposition of the sample and the top of the crucible is cooled sufficiently to prevent loss of alkali by vaporization. For routine analysis, however, the results obtained by the hydrofluoric-acid method are satisfactory, provided it is kept in mind that the method gives slightly low results.

When working with materials capable of complete decomposition with the hydrofluoric-acid mixture, this procedure gives results as accurate as those obtained by the J. Lawrence Smith method and possesses the advantage of direct determination of the total alkalis.

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SCREEN ANALYSES FOR PLANT CONTROL*

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ABSTRACT

A practical method of making screen analyses and of expressing the results is described. By the use of a second accumulation the analyses may be expressed numerically. Plotting the second accumulation data on a functional scale will allow checking the analyses for satisfactory grain-size distribution.

I. Introduction

The full significance of controlling screen analyses for plant control has been discussed for many years; but there has not been a simplified method for recording results for the plant foreman. The writer has endeavored to simplify the data to such a degree that the resulting graphs can be readily understood by the plant man as well as the executive. The method under discussion has been put to test for a number of years to prove its worth. Its simplicity has permitted the method to be introduced and established throughout this organization with little or no opposition. The writer feels that his organization is introducing and giving to ceramists a greatly needed method for controlling grain size in the plant. The necessity of having size of grain controlled can be appreciated after considering its importance in relation to shrinkage, refractoriness, load-carrying ability, density, slag resistance, and spalling.

The problems involved in working out this method were (1) to duplicate screen analyses, (2) to have a system readily usable at the mills, (3) to employ mesh numbers directly, (4) to require only simple arithmetical calculations, (5) to permit ready and intelligent comparisons, and (6) to present a vivid picture of the percentages caught on the finer screens.

II. Collection of Sample

The sample is taken as a grab sample, at definite intervals, from the final mix. In the case of the dry-press process, a brick is broken down for quartering according to the A.S.T.M. standard. A sample of approximately 500 grams is used. Samples of hand-made mud are taken at the table

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or aging piles. In all cases the sample must be uniform and representative of the mix. The dry sample for pre-grain sized material is collected after it is ground ready for use in mix.

III. Procedure for Wet-Screen Analysis

The quartered sample is treated according to the Tentative Method of Test for Particle Size of Ground Refractory Materials (A.S.T.M. Designation: C92–32T) procedure for wet-sieve analysis. The sample is weighed and dried until it is constant in weight. This requires four hours, with a maximum temperature of 120°C. The

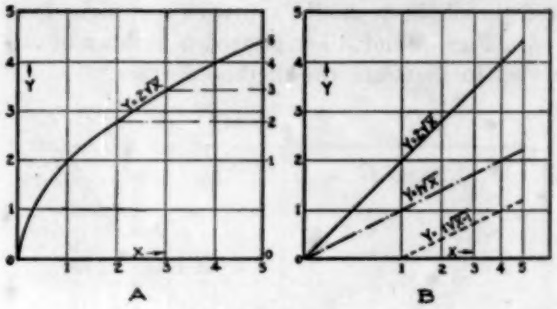

FIG. 1.

sample is weighed, and the moisture content are calculated. One hundred grams of the sample is placed in a 500 cubic-centimeter container and sufficient water is added to form a slurry. The mix is allowed to slake for one hour. The sample is transferred to a 200-mesh sieve and washed until the water passing through is clear.

The sample on the sieve is dried for two hours at 120°C, weighed, and the percentage of material washed through the 200-mesh sieve is calculated.

The dried and washed sample is then placed in the coarsest sieve of the series and shaken in a Ro-Tap for 15 minutes. The series of sieves used is the Tyler standard series, Nos. 4, 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, and 200. All of the screens of this series can be used at one time if half-height sieves are used.

IV. Calculation of Data and Plotting of Results

The weight of material caught on each screen is recorded in the column "sample weights." The percentage retained on each screen is calculated and recorded in "per cent" column. The "per cent cumulative weights" are obtained by taking a running total and entering in the space opposite each mesh. This is standard practice.

In the column headed "second accumulation divided by 100," a second running total is accumulated as in the previous case and entered opposite the mesh.

The "per cent cumulative weights" are plotted on the special graph paper in the usual manner, using the vertical scale on the left-hand side of the paper.

The data for the "second accumulation" are plotted using the right-hand vertical scale. The point at which this straight line cuts the base line and its height at the 200-mesh line gives the

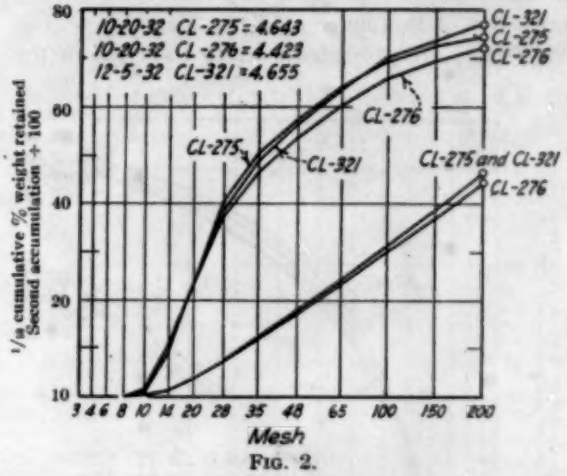

FIG. 2.

relative fineness of the whole grind. Its slope gives the graduation from the coarse to fine, and the more nearly the points fall on the line, the closer does the grind approximate what is desired.

V. Development of Form of Graph Paper

It was found necessary to provide some type of graph paper that would give the proper interpretation of the grain sizing. In search for a method of expressing grain-size distribution, the second accumulation was inspected. (The final figure for the second accumulation is a modification of Abrams' fineness modulus.)[1] It was found that the plot of the second accumulation for the mixes with superior grain-size distribution approached a straight line when a log scale for the openings of the screens was used. It was decided to use a functional scale for the screen sizes to bring this plot to a straight line.

[1] Duff A. Abrams, "Design of Concrete Mixtures," Structural Material Research Lab., Lewis Institute, *Bull.*, No. 1 (from Tyler Catalogue, 1924)

The use of a functional scale may be illustrated by a simple formula. In Fig. 1 (*A*) is plotted the curve $Y = 2\sqrt{X}$, where Y is the ordinate and X, the abscissa. Since the lines making up the cross-sectional field are all equally spaced, both the X and Y scales are said to be linear and uniform.

In Fig. 1 (*B*), the same curve is plotted as a straight line making an angle of 45° to the horizontal. The scale, X, in this case is functional and can easily be constructed by making the spacing between any two successive vertical lines correspond to the rise in Y of the original curve in the interval which the two vertical lines as abscissas are to represent. For example, the two ordinates of the curve at $X = 2$ and $X = 3$ in Fig. 1 (*A*) are projected over to the right in the two dot-and-dash lines, 2 and 3, and the distance between them is duplicated in spacing the two vertical lines, 2 and 3, in Fig. 1 (*B*). In Fig. 1 (*B*) are plotted two variations of the formula. It will be noted that these lines are straight also.

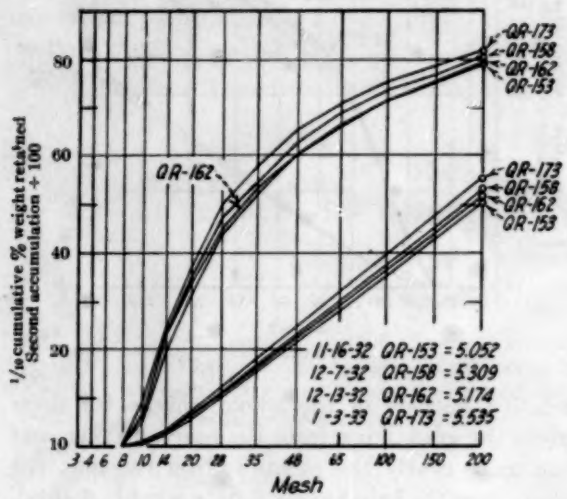

FIG. 3.

If it is desired to plot on cross-section paper any data which may be highly empirical and yet to have the plot approximate a straight line, the first step is to approximate the data by an empirical equation. After attaining, by trial and error, an equation which fits to a satisfactory degree, this is used as the law for a non-linear spacing of verticals in the required field.

Table I shows a comparison between such empirical data and an equation which closely approaches it in the range between 28-mesh screen and 200-mesh, inclusive. The data were averages resulting from the screen analysis of a number of grindings considered as having desirable characteristics. The equation is

$$Y = 0.51\left(\frac{1}{\sqrt{X}} - \frac{0.016}{X}\right) - 2.32.$$

It was not to be expected, of course, that other grindings should confirm this equation accurately. It was found, however, that every desirable grinding could be approximated by an equation of the same form, that is,

$$Y = a\left(\frac{1}{\sqrt{X}} - \frac{0.016}{X}\right) \pm c,$$

and these curves should approach a straight line.

On Figs. 2 and 3 are plotted a number of analyses to illustrate the method further.

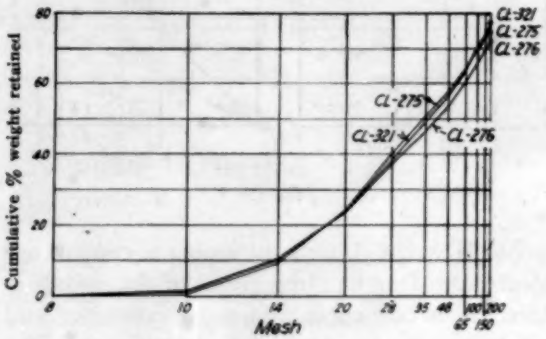

FIG. 4.

It will be noted that the fineness of several samples of a given material or mixture may be described satisfactorily by the final figure of the second accumulation, the fineness modulus. This figure is especially valuable for plant use.

Figure 2 gives a series of curves of a mix at various dates. This mix can be compared with mixes of similar characteristics from other plants of this Company. Figure 3 gives curves taken from another plant at various times.

Figure 4 shows some of the data formerly used.

VI. Summary

(1) A suitable fineness modulus for use in the plant on a given material is described.

(2) Through the use of a second accumulation and graph paper with a functional scale for the screen openings, the grain-size distribution may be checked against a standard.

TABLE I

Mesh No.	28	35	48	65	100	150	200
X (opening (in.))	0.0232	0.0164	0.0116	0.0082	0.0058	0.0041	0.0029
Y (2nd accumulation found)	0.69	1.15	1.69	2.29	2.96	3.65	4.38
Y (calculated from formula)	0.67	1.17	1.71	2.32	2.97	3.64	4.32

TABLE II

Mesh	CL-275			CL-276			CL-321		
	(%)	Cumulative weights (%)	Second accumulation ÷ 100 (%)	(%)	Cumulative weights (%)	Second accumulation ÷ 100 (%)	(%)	Cumulative weights (%)	Second accumulation ÷ 100 (%)
6	0.00	0.00	0.000	0.00	0.00	0.000	0.00	0.00	0.000
8	0.00	0.00	0.000	0.00	0.00	0.000	0.20	0.20	0.002
10	0.70	0.70	0.007	1.80	1.80	0.018	1.40	1.60	0.018
14	8.80	9.50	0.102	9.00	10.80	0.126	9.00	10.60	0.124
20	15.00	24.50	0.347	13.30	24.10	0.367	13.50	24.10	0.365
28	16.10	40.60	0.753	13.50	37.60	0.743	14.70	38.80	0.753
35	10.20	50.80	1.261	9.00	46.60	1.209	10.30	49.10	1.244
48	7.00	57.80	1.839	7.00	53.60	1.745	7.40	56.50	1.809
65	6.40	64.20	2.481	6.50	60.10	2.346	7.10	63.60	2.445
100	5.40	69.60	3.173	5.90	66.00	3.006	6.80	70.40	3.149
150	2.80	72.40	3.897	3.60	69.60	3.702	3.20	73.60	3.885
200	2.20	74.60	4.643	2.50	72.10	4.423	3.40	77.00	4.655
Pan	25.40			27.90			23.00		
Total	100.00	100.00		100.00	100.00		100.00	100.00	

TABLE III

Mesh	QR-153			QR-158			QR-162			QR-173		
	(%)	Cumulative weights (%)	Second accumulation ÷ 100 (%)	(%)	Cumulative weights (%)	Second accumulation ÷ 100 (%)	(%)	Cumulative weights (%)	Second accumulation ÷ 100 (%)	(%)	Cumulative weights (%)	Second accumulation ÷ 100 (%)
6	0.00	0.00	0.0000	0.00	0.00	0.000	0.00	0.00	0.000	0.00	0.00	0.000
8	0.08	0.08	0.0008	0.20	0.20	0.002	0.40	0.40	0.004	0.32	0.32	0.003
10	5.32	5.40	0.0536	6.89	7.09	0.0729	8.00	9.00	0.094	9.00	9.32	0.096
14	14.70	20.10	0.2566	16.73	23.82	0.3131	14.65	23.65	0.320	16.10	25.42	0.350
20	11.57	31.67	0.5733	11.24	35.06	0.6617	10.75	34.40	0.6645	12.24	37.66	0.727
28	12.51	44.18	1.0151	12.24	47.30	1.1347	11.16	45.56	1.120	12.62	50.28	1.230
35	8.05	52.23	1.5374	7.56	54.86	1.683	8.06	53.62	1.656	7.86	58.14	1.811
48	7.97	60.20	2.1394	7.89	62.75	2.310	6.52	60.14	2.257	7.29	65.43	2.456
65	6.02	66.22	2.8016	5.95	68.70	2.997	5.78	65.92	2.916	5.52	70.95	3.175
100	5.16	71.38	3.5154	5.02	73.72	3.735	5.44	71.36	3.630	4.56	75.51	3.930
150	3.60	74.98	4.2652	3.21	76.92	4.504	3.83	75.19	4.382	3.17	78.68	4.777
200	3.83	78.81	5.0533	3.55	80.48	5.309	4.03	79.22	5.174	3.11	81.79	5.535
Pan	21.19			19.52			20.78			18.21		
Total	100.00	100.00		100.00	100.00		100.00	100.00		100.00	100.00	

Acknowledgment

The author wishes to acknowledge the part played by Charles F. Sweney in collecting many of the data in the calculations which led to the final solution of the problem.

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THE EFFECT OF THE SOLID-LIQUID RATIO ON GRINDING A CERAMIC NONPLASTIC*

By Karl Schwartzwalder and Paul G. Herold

Abstract

A ceramic nonplastic (specific gravity 3.04) was wet-ground with solid-liquid ratios of 2.7 to 1 and 1 to 15 for various lengths of time. Grain-size distribution and surface area, as measured by the Wagner turbidimeter method, were compared. The material ground with the least water gave a lower percentage retained on a 325-mesh screen, fewer particles between 10 and 60 microns, and more between 0 and 10 microns.

I. Introduction

Considerable experimental work has been reported on the grain-size distribution of finely ground ceramic nonplastics, particularly feldspar and flint, dry-ground in continuous or batch mills. Schramm and Scripture[1] determined by means of water elutriation the grain-size distributions of various feldspars and flints ground dry in tandem Hardinge mills followed by air separation, as well as in batch mills. These grain-size distributions indicated that, while the percentage of particles coarser than 325-mesh was approximately the same, the relationship of the particle sizes finer than 325-mesh depended upon the particular method of dry grinding. The results obtained on the feldspars were checked by cone deformation tests. Vieweg[2] showed that it was possible to predict the grain-size distribution of feldspars and flints, dry-ground in a batch mill, by a size-frequency law. Practically no data have been published giving the grain-size distribution or the possibilities of obtaining various grain-size distributions by the use of wet-grinding methods. In laboratory investigations of various nonplastics of a porcelain body, it is often desirable to duplicate by wet grinding in small laboratory batch mills the grain-size distribution obtained by dry grinding on a production scale in a Hardinge mill. Previous experience of the writers indicated that control of the percentage of nonplastic particles coarser than 325-mesh alone in these small batches did not result in obtaining insulator porcelains having physical characteristics similar to the production processed material. An attempt was made to duplicate grain sizes and at the same time to determine if, by varying those factors affecting wet grinding conditions, various grain-size distributions could be obtained and controlled.

II. Experimental

The solid (nonplastic)-liquid (water) ratio and the grinding time were chosen in this particular case as the variable factors. A series of grinds was made using a solid-liquid ratio of 2.7 to 1 and grinding periods of 15, 30, 45, and 60 minutes. The results of these tests were compared with those in which a solid-liquid ratio of 1 to 15 with grinding periods of 30, 60, and 120 minutes was maintained. These two ratios were chosen as representing extreme cases. The nonplastic used in these experiments was an electric furnace mullite which previously had been ground to pass an 8-mesh screen.

Each grinding test was carried out separately on a laboratory scale in a 4- by 5-foot mill with 75 pounds of nonplastic being ground at one time. The following conditions were maintained constant to obtain comparable results: pebble size $^3/_4$ inch diameter; pebble-solid ratio 12:1, speed of mill 35 r.p.m. The nonplastic, after being ground, was emptied from the mill into pans, dried in a steam drier, thoroughly mixed, and sampled in a riffle sampler. The sample could have been taken directly from the mill without unloading but, in order to be certain that no settling had occurred, the ground materials were dried and mixed before being sampled.

III. Method of Determining Grain-Size Distribution

While the grain-size distribution of the ground nonplastic could have been determined by several known methods used in the ceramic industry, an investigation was undertaken to determine the

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (White Wares Division). Received June 8, 1935.

[1] E. Schramm and E. W. Scripture, Jr., "Particle-Size Distribution of Typical Feldspars and Flints," *Jour. Amer. Ceram. Soc.*, **10** [4] 264–67 (1927).

[2] H. F. Vieweg, "Particle-Size Distribution in Some Ground Ceramic Raw Materials," *ibid.*, **18** [1] 25–39 (1935).

method most suitable for this particular grinding problem as well as useful for production control purposes. A review of the literature and the results obtained in this study disclosed that (1) the microscopic method[3] of measuring particle-size distribution was time-consuming for material finer than 325-mesh and required a trained operator and (2) only a few of the methods involving elutriation or settling in gas or liquid could be used for practical control purposes. Of these latter methods, the one developed by Wagner[4] for use in determining surface area of Portland cement seemed to be best adapted to measure various ceramic nonplastic materials.

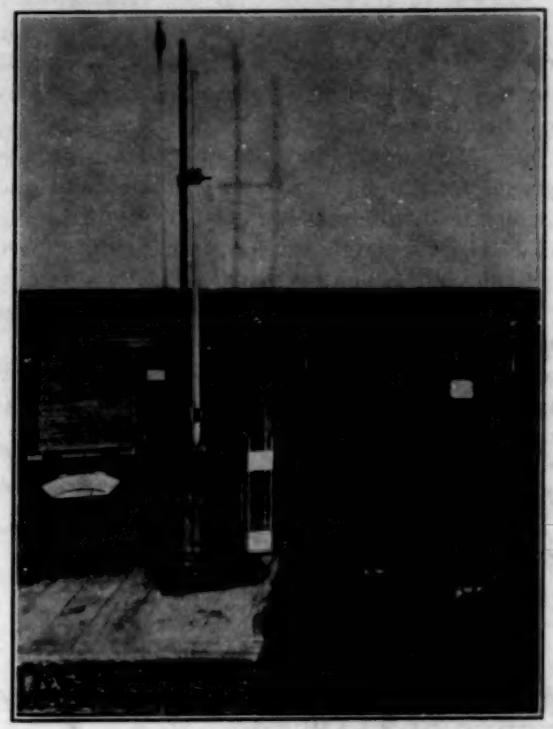

FIG. 1.—The Wagner turbidimeter.

The Wagner turbidimeter (Fig. 1) consists of a source of light of constant intensity which passes through a liquid suspension of the nonplastic material to a photo-electric cell where the current generated is measured by a microammeter. The suspending liquid for the nonplastic may be any

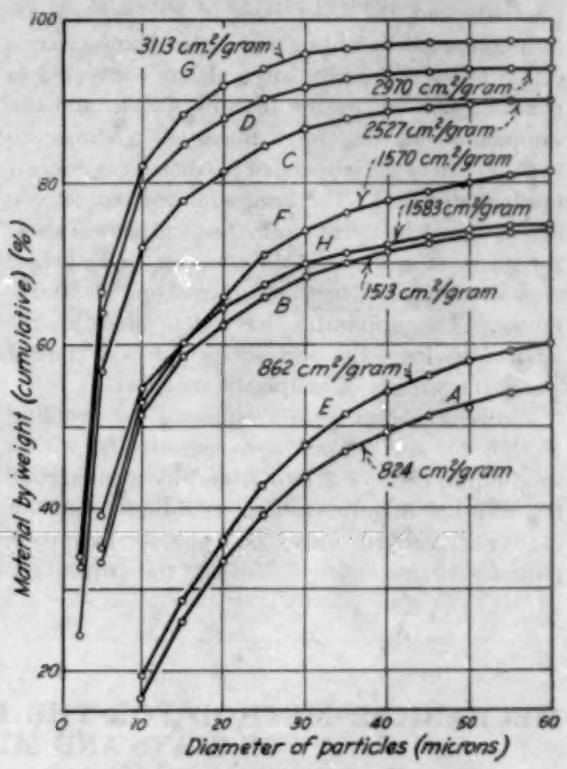

FIG. 2.—Grain-size distribution of nonplastic.

A, ground 15 min. with solid-liquid ratio 2.7:1
B, " 30 " " " " " 2.7:1
C, " 45 " " " " " 2.7:1
D, " 60 " " " " " 2.7:1
E, " 30 " " " " " 1:15
F, " 60 " " " " " 1:15
G, " 120 " " " " " 1:15
H, " Hardinge mill

[3] W. L. Fabianic, "Microscopic Control of Particle Size in Refractory Manufacture," *Jour. Amer. Ceram. Soc.*, **18** [1] 23–25 (1935).

[4] L. A. Wagner, "Rapid Method for Determination of Specific Surface of Portland Cement," *Proc. A.S.T.M.*, **33** [Part II] 553–70 (1933).

TABLE I
NONPLASTIC GROUND IN BALL MILL

	Diagonal diameter*	Side diameter†	Solid-liquid ratio of 2.7 to 1 grinding time					Solid-liquid ratio of 1 to 15 grinding time		
			15 min. (%)	30 min. (%)	45 min. (%)	60 min. (%)	Hardinge mill (%)	30 min. (%)	60 min. (%)	120 min. (%)
On 150-mesh	147 microns	104 microns	8.3	0.6	0.1	0.7		3.5	0.2	0.1
On 200- "	105 "	74 "	23.3	7.2	1.1	0.8		16.8	4.3	0.8
On 250- "	86 "	61 "	30.0	16.8	4.1	1.6		30.0	10.1	1.7
On 325- "	60 "	43 "	44.6	25.3	9.6	5.8	24.8	39.4	19.2	2.4
Between 10 and 60 microns			38.7	23.2	18.2	14.5	20.5	41.1	27.6	31.0
Between 0 and 10 microns			16.7	51.5	72.2	79.7	54.7	19.5	53.2	66.6
Surface area (sq. cm./gram)			824	1513	2527	2970	1583	862	1570	3113

* The maximum particle size that the screen can pass when the diagonal of the square is taken as the diameter.
† The maximum particle size that the screen can pass when the side of the square is taken as the diameter.

suitable liquid as determined by the characteristics of the nonplastic, and an electrolyte may be added to disperse any agglomerates that tend to form. The data recorded are the settling-time intervals and the intensities of the light beam in microamperes falling upon the photo-electric cell. The settling-time intervals are converted to particle sizes by means of Stokes' law, and the conversion of the microammeter readings to surface area of the suspended particles is developed mathematically.[4] The results for any one sample are obtained in twenty minutes and give a measurement of grain-size distribution and surface area which closely parallels microscopic measurements. The apparatus has been used in the laboratory for some time in production control work on a variety of nonplastic materials.

Figure 2 shows results obtained by grinding 15, 30, 45, and 60 minutes, respectively, with a solid-liquid ratio of 2.7 to 1, and by grinding 30, 60, and 120 minutes with a solid-liquid ratio of 1 to 15. Table I shows the screen analysis of particles coarser than 325-mesh, the percentage of material between 10 and 60 microns, and between 0 and 10 microns.

IV. Conclusions

(1) The Wagner turbidimeter is suitable for the rapid determination of the surface area and grain-size distribution of many fine-grained nonplastic materials.

(2) The results indicate that by using the proper solid-liquid ratio and grinding time, the grain-size distribution obtained by dry grinding in a Hardinge mill can be duplicated by wet grinding in a laboratory batch mill.

(3) For the same grinding time, a solid-liquid ratio of 2.7 to 1 resulted in a decrease in percentage of particles coarser than 325-mesh, a decrease in percentage of particles between 10 and 60 microns, and an increase in percentage of particles below 10 microns when compared to a solid-liquid ratio of 1 to 15 per unit time.

A C Spark Plug Company
Flint, Michigan

MECHANICAL METHOD FOR THE MEASUREMENT OF THE PLASTICITY OF CLAYS AND MIXTURES OF CLAYS*

By J. W. Whittemore

Abstract

A method of measuring the plasticity of clays and mixtures of clays is presented. An apparatus is described by which the penetration of a constantly loaded hemisphere into a plastic clay mass during a definite time period is measured. The data indicate that the formula, $d = at^P$, expresses the relationship between d, the amount of penetration, during t, the time periods studied for any clay. Undoubtedly a is related to the load used, the diameter of the hemisphere, and some of the properties of the clay; P, in the formula, is a measure of the plastic properties of the clay. The data also show, through the variations in the value of P, the marked change in plasticity of a clay caused by changes in grinding, aging, and de-airing of a clay.

I. Introduction

Plasticity is commonly defined as that property of a clay which enables it, when wetted, to be molded without rupture into any desired shape which will be retained after removal of the deforming force. Ries[1] defines plasticity as "the property which many bodies possess of changing form under pressure, without rupturing, which form they retain when the pressure ceases, it being understood that the amount of pressure required and the degree of deformation possible will vary with the material." Both of these definitions really define plasticity in terms of deformability and, according to Searle,[2] "if plasticity may rightly be defined in terms of deformability, it is clear that the only rational

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (White Wares Division).

[1] H. Ries, Clays—Their Occurrence, Properties, and Uses, p. 165.

[2] A. B. Searle, The Chemistry and Physics of Clays and Other Ceramic Materials, p. 277.

methods of measuring plasticity must be of a mechanical nature and that they must measure the pressure required to alter the shape of the plastic mass to a definite extent within a definite period of time."

II. Test with Flat-Ended Plunger

An apparatus was built (see Fig. 1), in which a constantly increasing load of mercury, controlled by an overflow constant head arrangement, is

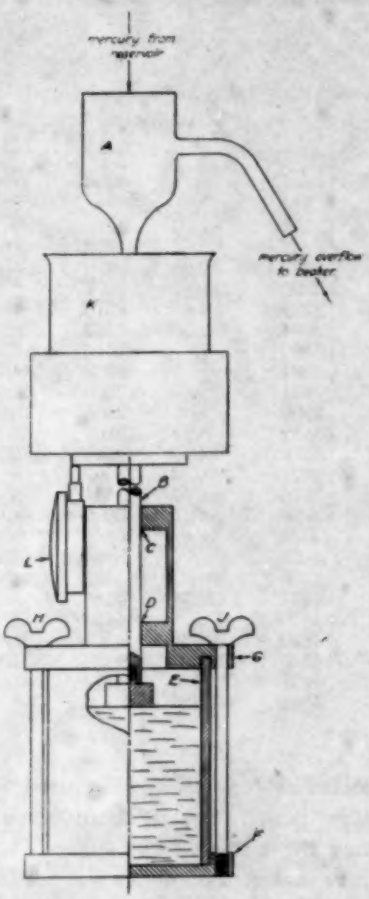

FIG. 1.—*A*, constant head device; *B*, shaft and plunger; *C* and *D*, shaft bearings; *E*, clay cylinder; *F* and *G*, base and top; *H* and *J*, wing nut bolts; *K*, beaker; *L*, dial micrometer.

applied to the upper end of a shaft. The lower end of the shaft has a flat-ended plunger one inch in diameter. The clay to be tested is pressed into a steel cylinder and the cylinder is clamped to the part of the apparatus with the moving shaft and the plunger. The movement of the shaft at definite time periods is recorded and by this means the definite force required to deform a clay to a definite extent in a definite time is obtained.

Several clays were tested with this apparatus and the results of the tests on two of the clays are shown in Table I. These two clays were chosen

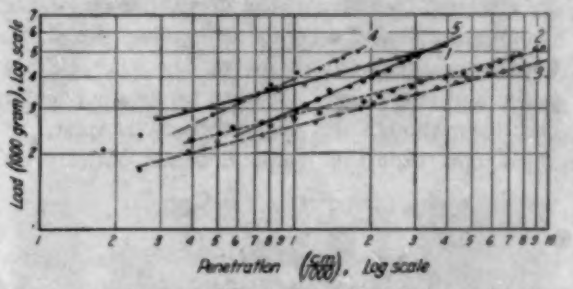

FIG. 2.—Load-penetration curves; plasticimeter with flat plunger.

because of their apparent distinct differences in plastic properties. One of them was a Kentucky ball clay, and the other was an alluvial sandy clay. These clays were prepared for the test in the same manner.

Plotting the logarithms of the total loads (see Fig. 2) in grams at definite time periods as

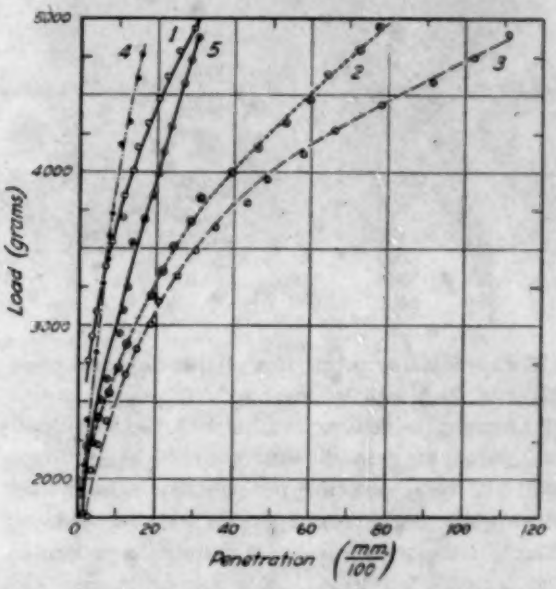

FIG. 3.—Load-penetration curves; plasticimeter with flat plunger.

ordinates and the logarithms of the corresponding penetrations of the shaft during the same time periods as abscissas, the points are found to lie on a straight line. It is to be noted (as shown in Fig. 2) that, although the water content for the same clay was varied, the logarithmic curves are

parallel. These curves show that the movement of the shaft, or depth of penetration, d, in a definite extent of time is related to the penetrating load, w, as follows, $w = ad^m$.

It is thought that the factor, a, depends on the amount of water in the clay, the size of the penetrating shaft, the rate of loading the shaft, and certain characteristics of the clay. Since m remains very nearly constant for any particular clay even though the water content is varied, it is thought that this value depends entirely on the character or properties of the clay and probably on its plasticity.

Plotting these same results with the total loads in grams at definite time periods as ordinates and the corresponding penetrations of the shaft during the same time periods as abscissas (see Fig. 3), the points follow a parabolic curve.

TABLE I

PENETRATION OF A FLAT-ENDED PLUNGER WITH A CONSTANTLY INCREASING LOAD

	Ball clay						Alluvial clay			
	32.2% H_2O		34.2% H_2O		36.2% H_2O		21.8% H_2O		22.25% H_2O	
Time (sec.)	Load (g.)	Penetration (cm.)	Load (g.)	Penetration (cm.)	Load (g.)	Penetration (cm.)	Load (g.)	Penetration (cm.)	Load (g.)	Penetration (cm.)
110					1743	0.00248				
120					1902				1772	0.00127
130					2060	.00388	1937	0.00105	1920	
140			2240	0.00394	2219	.00508	2086	.00180	2067	
150			2400	.00513	2377	.00756	2235		2215	.00208
160			2560	.00810	2536		2384	.00250	2363	.00304
170			2720	.01003	2694	.01239	2532		2510	.00584
180	2777	0.00291	2880	.01255	2853	.01519	2682		2658	.00751
190	2931	.00378	3040		3011	.01849	2831	.00485	2806	
200	3086	.00485	3200	.01897	3170	.02052	2980		2954	.01021
210	3240		3360	.02182	3328	.02547	3129		3101	.01125
220	3394	.00717	3520	.02436	3487	.03042	3278	.00615	3249	.01252
230	3549	.00872	3680	.02913	3645	.03637	3427	.00732	3397	
240	3703	.01110	3840	.03157	3804	.04320	3576	.00795	3544	.01386
250	3857	.01118	4000	.03949	3962	.04833	3725	.00815	3692	.01668
260	4011	.01357	4160	.04608	4121	.05819	3874		3840	.01899
270	4166	.01499	4320	.05316	4279	.06604	4023		3987	.02026
280	4320	.01800	4480	.05958	4438	.07863	4172	.01022	4135	.02145
290	4474	.02005	4640	.06449	4596	.09133	4321	.01274	4283	.02382
300	4629	.02218	4800	.07276	4755	.10231	4470		4431	
310	4783	.02533	4960	.07729	4913	.11176	4619	.01475	4578	.02669
320	4937	.02933	5120	.08879	5072	.12479	4768	.01560	4726	.02809
330	5092	.03170	5280	.09512	5230	.13736	4917		4874	.03086
340	5246	.03607	5440		5389	.15488	5066	.01785		
350	5400	.03912								

III. Test with Hemispherical Plunger and Constant Load

From the first it was realized that the flat-ended shaft introduced an error that could not be controlled. False results would be obtained in testing clays containing large grains that might be so located at the end of the shaft that part of the grain would extend beyond the circumference of the shaft. The protruding grains would actually increase the area of the clay acted upon by the deforming load and give results that could not be compared with the results on the same clay when ground finer or on another clay containing finer grains.

McBurney[3] suggests the use of a hemisphere in place of the flat-ended plunger and a constant load on the shaft. With the spherical surface and a constant load, there is actually an ever-changing load per area of contact.

A large hemisphere should be used to attain considerable penetration without even closely approaching the radius of the sphere. A hemisphere, three inches in diameter was used throughout these tests.

With some clays, a slight load would cause some penetration and any tendency of impact due to accelerated travel of the plunger would give pseudo results.

The apparatus as finally constructed is shown in Figs. 4 and 5.

The weight of the shaft, a (Fig. 4), with the hemispherical end is counter-balanced by the lever arm and weights, b, so that the hemisphere

[3] J. W. McBurney, "Indentation of Asphalt Tile," *Proc. A.S.T.M. 37th Annual Meeting, Tech. Papers* (Part II), pp. 591–603 (1934).

may be lowered with the least possible impact onto the clay and no penetration will result before the test is started.

The clay is enclosed in the base, *c*. The clay is rammed into the base by means of a hydraulic ram. A small hole in the base allows the air to escape as the clay is rammed into it.

After the hemisphere is lowered onto the clay very carefully to prevent impact, the zero reading of the micrometer dial is taken. The bottle is

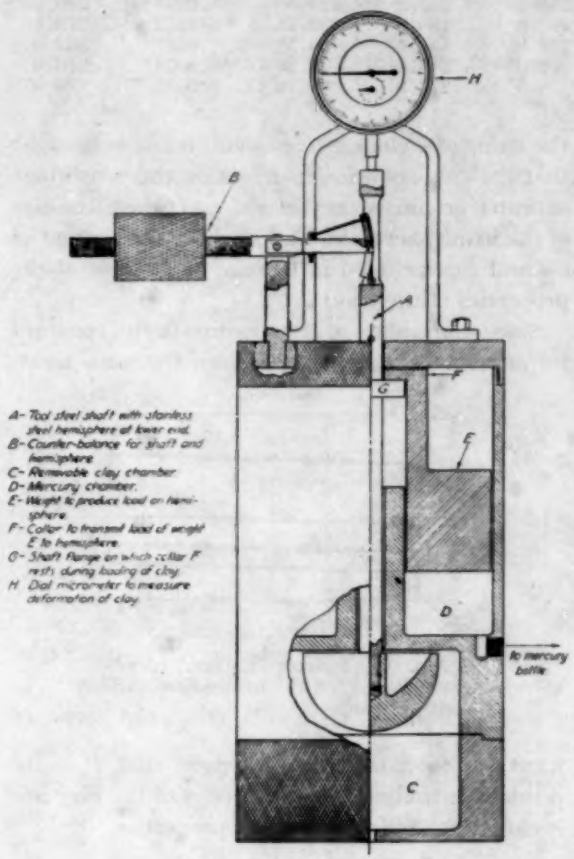
H
B
A
F
G
E
D
C
To mercury bottle
A- Tool steel shaft with stainless steel hemisphere at lower end.
B- Counter-balance for shaft and hemisphere.
C- Removable clay chamber.
D- Mercury chamber.
E- Weight to produce load on hemisphere.
F- Collar to transmit load of weight E to hemisphere.
G- Shaft flange on which collar F rests during loading of clay.
H Dial micrometer to measure deformation of clay.

FIG. 4.

then lowered allowing the mercury in chamber *d* to flow into the bottle. The mercury, while in the chamber, floats the weight, *e*, and as soon as the mercury is removed the weight lowers until its collar at *f* rests on the flange, *g*, of the shaft with the hemispherical end. The hole in chamber *d*, through which the mercury flows, is small enough to lower the weight slowly, thus reducing the amount of impact when the weight comes in contact with the flange on the shaft; the mercury, however, lowers the weight *fast enough* to apply the full load to the clay as soon as it comes in contact with the flange on the shaft.

The mercury should be allowed to flow from the plasticimeter at two places, 180° apart, so that the weight is lowered evenly.

A dial micrometer, *h*, reading to $^1/_{10,000}$ inch, is supported above the upper end of the shaft and in contact with the end of the shaft. By this means the depth of penetration of the hemisphere into the clay may be read accurately to $^1/_{10,000}$

FIG. 5.

inch. Readings of the dial were taken with a stop-watch at 30 seconds and 1, 5, and 10 minutes.

As soon as the plunger was lifted, approximately 100 grams of the clay mass were removed, and the water of plasticity was determined by the standard method as recommended by the American Ceramic Society.[4] Care was taken to obtain the sample immediately below the imprint left by the plunger.

The equipment was placed upon a pneumatic cushion to prevent any vibrations affecting the readings.

Several clays were tested with this equipment, some of them with varying periods of aging and varying amounts of grinding, pugging, and de-

[4] *Jour. Amer. Ceram. Soc.*, 11 [6] 449 (1928).

TABLE II

PENETRATION OF A 3-INCH SPHERE WITH A CONSTANT LOAD OF 15 POUNDS IN VARIOUS CLAYS

Test No.	Type of clay	Penetration (in mil.) (30 sec.)	(1 min.)	(5 min.)	(10 min.)	Water of plasticity	(P)	(a)
1	Va. shale	146.6	147.7	150.0	150.8	24.09	0.0090	147.7
2	" "	139.3	140.4	142.5	143.1	23.85	.0084	140.3
3	" "	254.5	257.1	260.6	262.0	27.68	.0082	257.0
4	Ball clay No. 1	146.9	148.4	151.9	153.4	37.13	.0144	148.4
5	" " " "	134.1	135.5	138.7	140.1	37.68	.0146	135.5
6	Plastic kaolin	265.5	268.4	274.1	276.4	45.84	.0128	268.4
7	Ball clay No. 2	128.0	130.0	133.1	134.7	44.56	.0153	130.0
8	Pottery clay		317.7	336.0	340.1	24.47	.0296	317.7
9	Grogged fire clay	169.3	170.6	172.9	173.7		.0078	170.6
10	Pottery clay No. 2		205.0	209.3	210.8	24.18	.0121	205.0
11	Whiteware mixture		250.9	256.2	258.2	25.65	.0125	250.9
12	" "		240.2	245.4	247.2	25.50	.0125	240.2
13	" "		278.1	283.8	286.0	22.74	.0122	278.1
14	" "		332.0	338.8	341.4	34.52	.0121	332.0
15	Va. shale		310.0	314.0	315.3	32.31	.0074	310.0
16	" "		275.0	278.5	279.8	32.19	.0075	275.0

airing. The results of some of these tests are shown in Table II.

IV. Results

Plotting the results of any one of these tests with the logarithms of the depths of penetration as ordinates and the logarithms of the corresponding times as abscissas, the points lie on a straight line. Therefore the equation, $d = at^P$, holds for the relation between the depth of penetration, d, of the hemisphere into the clay and the corresponding time, t. The results fulfill the requirements of the definitions that have already been given for plasticity of clay, since at any definite time the sphere with its constant load has deformed the clay to a definite extent. It may be noted that although a varies considerably for any clay, the value of P remains fairly constant for that clay.

By varying the amount of water in the clay, the value of a changes considerably; it is thought that the value of a is dependent on the percentage of water or consistency of the clay mass, the size of the hemisphere, the load applied, the content of air and gas included in the clay, and some of the properties of the clay.

Since the value of P remains fairly constant for any clay as long as it is given the same treatment for each test, it is thought that P is dependent entirely on the properties of the clay and is closely related to its plastic properties.

TABLE III

EFFECT OF AGING THE CLAYS ON THE VALUE OF P AND a

Test No.	Type of clay	Age of clay (days)	P	a	Water of plasticity (%)
1	Va. shale	0	0.0074	310.0	32.31
2	" "	10	.0082	257.0	27.68
3	" "	14	.0087	206.5	26.06
4	" "	39	.0100	153.9	23.54
5	" "	46	.0104	166.7	24.27
6	Ball clay No. 1	0	.0153	130.0	44.56
7	" " "	1	.0161	137.3	44.28
8	" " "	3	.0188	132.6	43.61
9	" " "	29	.0211	121.6	37.35
10	" " "	33	.0225	116.5	38.86
11	" " No. 2	0	.0146	135.4	37.68
12	" " "	1	.0160	146.6	36.74
13	" " "	5	.0166	131.5	36.53
14	" " "	32	.0192	110.8	32.98
15	" " "	36	.0213	77.7	29.54

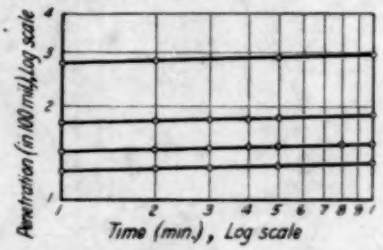

FIG. 6.—Penetration-time curves; plasticimeter with hemisphere and constant load.

V. How Plasticity Is Varied

There are several ways of increasing the plasticity of a clay, *e.g.*, by the addition of a reagent which causes flocculation (the addition of the H ion), fine grinding, aging, and de-airing. There are also ways of decreasing the plasticity of clay, *e.g.*, the addition of grog, air, or of a reagent which causes deflocculation (certain amounts of the OH ion).

(1) Effect of Aging

Table III shows the effect that the aging of the clays has on the value of P. The clays after

pugging were placed in a damp box and stored. The damp box used was kept closed and as much care as possible was used to keep the test samples from drying out, but it may be noted that the amount of water of plasticity decreased with time, showing that the samples had dried considerably.

TABLE IV

EFFECT OF DE-AIRING AND THE ADDITION OF A FLOCCULENT ON THE VALUE OF P AND a

Test No.	Type of clay	Treatment and additions	P	a	Water of plasticity
1	Va. shale	None	0.0074	310.0	32.31
2	" "	0.125% floc-culent	.0106	137.8	31.85
3	" "	De-aired	.0131	52.4	26.34
4	" "	0.125% floc-culent and de-aired	.0187	88.5	27.88
5	Sagger clay	None	.0212	185.6	30.95
6	" "	1.00% floc-culent	.0332	75.5	26.66
7	" "	1.50% floc-culent	.0330	67.2	26.57
8	" "	2.00% floc-culent	.0365	78.7	26.57
9	" "	De-aired	.0357	73.4	27.43
10	" "	1.25% floc-culent and de-aired	.0379	71.3	28.94
11	" "	1.50% floc-culent and de-aired	.0400	49.7	26.11
12	" "	2.00% floc-culent and de-aired	.0518	31.6	25.82
13	Grogged fire clay	None	.0078	170.6	20.31
14	" "	De-aired	.0107	103.8	19.73

In every case aging increased the value of P even though the water of plasticity and the value of a had decreased. As may be expected, the apparent plasticity (noted by feel) increased a great deal more for the ball clays than for the shale and, correspondingly, as the samples were aged, the values of P increased much more rapidly for the ball clays than they did for the shale.

(2) Effect of Acid and De-Airing

Table IV shows the result of adding an acid to the clay and also the effect of de-airing the clay. It will be noted that the value of P is greatly increased in both cases and, where both acid is added and de-airing is used, the value of P is several times greater than without these factors.

The refractory clay included in Table IV was received with the grog already in it. To all appearances, however, the clay itself was undoubtedly very much like the sagger clay and would probably have had a value of P equal to at least 0.0190. The grog reduced the value of P to 0.0078 and de-airing raised it to 0.0107.

VI. Effect of De-Airing on Recovery of Penetration

At the conclusion of each test, the load was removed and it was noted that the shaft was pushed up by the clay. It was found that this recovery of the penetration of the hemisphere in the clay had practically stopped in all cases after one minute, and readings were made at this time. The results of this recovery are shown in Table V. It may be noted that in those clays which were de-aired with 26 inches of vacuum there was no recovery, while those de-aired with only 22 inches of vacuum had a small percentage of recovery. Clays that were not de-aired had a much greater recovery. At first this recovery was attributed to the clay itself, but when samples were tested that had been thoroughly de-aired and no recovery was found after removal of load it was realized that this recovery was undoubtedly due to entrapped air that had been compressed

TABLE V

TOTAL PENETRATION AND RECOVERY AFTER REMOVAL OF LOAD

Test No.	Type of clay	Total penetration (mil.)	Recovery (in mil.)	Recovery (%)	Remarks
1	Va. shale	150.8	20.7	13.73	Not de-aired
2	" "	315.3	27.3	8.66	" "
3	" "	210.6	25.6	12.16	" "
4	" "	54.0	0.0	0.00	De-aired with 26-in. vacuum
5	" "	92.4	0.4	.43	De-aired with 22-in. vacuum
6	Ball clay	153.4	14.3	9.32	Not de-aired
7	Kaolin	276.4	4.2	1.52	" "
8	Pottery clay	210.8	13.8	6.55	" "
9	Whiteware clay	258.2	13.4	5.19	" "
10	Sagger clay	206.3	17.4	8.56	" "
11	" "	72.5	10.6	14.62	" "
12	" "	85.6	9.8	11.45	" "
13	" "	77.8	0.4	0.51	De-aired with 22-in. vacuum
14	" "	54.5	.2	.37	" " " " " "
15	" "	35.6	.3	.84	" " " " " "

by the load of the hemisphere. As soon as this load was removed, the pressure of the compressed air was able to lift the sphere. In tests where there was no compressed air in the clay to lift the sphere after removal of the load, the clay was completely and permanently deformed and no recovery was discernible.

To determine how closely all of the readings for any one test followed the equation determined by using the 1- and 10-minute readings, the equation was determined using all of the readings that were taken, namely, the penetration at 1, 2, 3, 4, 5, 6, 8, and 10 minutes. The values of a and P for the equations using all values are shown in Table VI, as well as the values using only the readings at 1 and 10 minutes and at 1, 5, and 10 minutes.

As with the original plasticimeter, if the results of the tests using this plasticimeter with the hemispherical plunger and the constant load are plotted with the depth of penetration as ordinates and the corresponding times as abscissas, the points follow a parabolic-type curve. It is believed from the results of these tests that even with slight loads there is some strain, and with many clays at loads too small to measure, the elastic limit or yield value of the material is reached. Beyond this yield value, the plastic properties of the clay are exhibited. Where plasticity is determined by forcing clay through an orifice and the load required to start flow is considered as the load necessary to exceed the yield value, it is believed a pseudo-result is obtained. Much of this load is absorbed in rearranging the grains and in compressing the air and gas contained in the clay. The test work and results on de-aired clays is the basis for this reasoning. Clays that have not been de-aired have considerable recovery after removal of the load, while completely de-aired clays have no measurable recovery.

VII. Practical Operation of the Apparatus

Since the equation determined by using 1- and 10-minute readings apparently satisfies all of the readings taken between these two, the determination of the values of a and P are greatly simplified. The value of a is the depth of penetration at unit time and can be determined directly from the 1-minute reading of the depth of penetration. The value of P can be determined very nearly as easily. The result of the subtraction of the logarithm of the penetration at unit time from the logarithm of the penetration at 10 minutes is the value of P.

In order that the work of different operators may be compared, specifications as to the preparation of the sample, etc., should be made.

Plans are under way to improve this apparatus and also to standardize the method and procedure.

TABLE VI

EFFECT ON THE VALUE OF P AND a WHEN READINGS (OTHER THAN THE 1- AND 10-MINUTE READINGS) ARE USED TO DETERMINE THE EQUATION OF RELATION BETWEEN DEPTH OF PENETRATION AND CORRESPONDING TIME

Test No.	Penetration (mil.) (1 min.)	(2 min.)	(3 min.)	(4 min.)	(5 min.)	(6 min.)	(8 min.)	(10 min.)	Using 1 and 10 readings		Using 1, 5, and 10 readings		Using all points	
									P		P	a	P	a
1	0.1240	0.1260	0.1269		0.1286			0.1310	0.0239	124.0	0.0240	124.0	0.0241	124.0
2	.1435	.1460	.1475	0.1485	.1490		0.1505	.1512	.0227	143.5	.0228	143.5	.0225	143.7
3	.3177	.3217	.3236	.3350	.3360		.3381	.3401	.0306	317.7	.0325	316.5	.0305	318.2
4	.1770	.1810	.1820	.1835	.1847	0.1855		.1880	.0262	177.0	.0263	177.0	.0263	176.9

VIII. Conclusions

(1) The apparatus as described gives a method by which the penetration into a clay mass of a 3-inch hemisphere with a load of 15 pounds may be measured at definite time intervals.

(2) With this apparatus, the relation between the penetrations and the corresponding time intervals may be expressed by the equation, $d = at^P$, where d is the depth of penetration, t the corresponding time, and a and P are constants.

(3) For any particular clay, the values of a and P remain constant as long as the treatment of the clay before testing is the same, provided the clay at each test contains the same amount of water of plasticity and the same amount of air and gas has been aged an equal length of time under the same conditions and contains equal amounts of nonplastics of the same size.

(4) The values of P remain the same and the values of a vary for any particular clay when the amount of water is varied and all other conditions remain the same.

(5) The values of P increase with aging of the

clay (it is well-known that plasticity of a clay is increased with aging).

(6) The values of P increase with additions of coagulators; coagulation increases plasticity.

(7) The values of P increase with de-airing. The blebs of included air in a clay act similar to grog and tend to reduce its plastic properties. The clay becomes more plastic with removal of the air.

(8) Since the value of P in any test is a relation of the definite amount of deformation of the clay caused by a definite load during a definite extent of time, the value of P may be considered as a numerical measurement of the plasticity of a clay. This is further proved by the increase of the value of P when the plasticity of a clay is improved by various methods.

(9) The amount of recovery of penetration of the sphere after removal of the load is a measure of the air and gas content of the clay.

(10) The value of a in the equation, $d = at^P$, is closely related to the air and water content of the clay.

(11) Further work should be done on the correct preparation of a clay before testing so that a specification may be used by which the results with two clays can be more correctly compared.

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RECENT REVISIONS OF HIGH TEMPERATURES*

By L. Donald Morris and S. R. Scholes

During the past few years, the application of advanced and painstaking work to the determination of certain fixed points for pyrometry at the higher temperatures has resulted in the establishment of points which differ so much from those previously accepted that they involve important changes in a number of temperatures of interest to ceramic technologists. The writers have thought it advisable to collect these data from scattered sources and to show what corrections must be made to the values previously accepted throughout the high-temperature scale in order that the ceramic data may be brought into line with the best available measurements.

The International Temperature Scale is a compilation of basic and reproducible equilibrium temperatures to which numerical values are assigned. The primary points of this scale are defined as the following equilibria at normal atmospheric pressure:

(1) Liquid and gaseous oxygen (oxygen point)	−182.97°C
(2) Ice and air-saturated water (ice point)	0.00
(3) Liquid water and water-vapor (steam point)	100.00
(4) Liquid sulfur and its vapor (sulfur point)	444.60
(5) Solid and liquid silver (silver point)	960.50
(6) Solid and liquid gold (gold point)	1063.00

Secondary points previously used are similarly defined as follows:

(1) Freezing tin	231.85°C
(2) Freezing zinc	419.45
(3) Freezing palladium	1549.00
(4) Melting tungsten	3400.00

No changes have been made lately in the fixed points up to and including the melting point of gold. Above this temperature, a number of freezing points have now been established with an accuracy that undoubtedly justifies including them as fixed points of reference. They differ from previously determined values as shown in the following table:

Freezing Points	Old (°C)	New (°C)	Difference
Nickel	1452	1455	+ 3
Palladium	1549	1555	+ 6
Platinum	1755	1773 ± 1	+ 18
Rhodium	1955	1966 ± 3	+ 11
Iridium	2350	2454 ± 3	+104

The value of 1455°C was determined by Wensel and Roeser when they measured the ratio of brightness of a certain wave-length of red light emitted by black bodies at the freezing points of nickel and gold, respectively. This is the general method of procedure which they and other workers have followed in determining other values cited in this paper. It is understood that different wave-lengths and other methods of securing black-body conditions at the freezing points of other metals

* Received June 14, 1934.

may have been used. The same authors are an authority for the value for palladium, 1555°C.

By the comparison of emissivity at the freezing points of gold and platinum, Roeser, Caldwell, and Wensel found the platinum point at 1773.5°C with a probable error of 1°C. Roeser and Wensel similarly established the rhodium point at 1966 ± 3°C. Apparently the older value for rhodium was more nearly acceptable in the light of improved methods than that for platinum. Henning and Wensel established the freezing

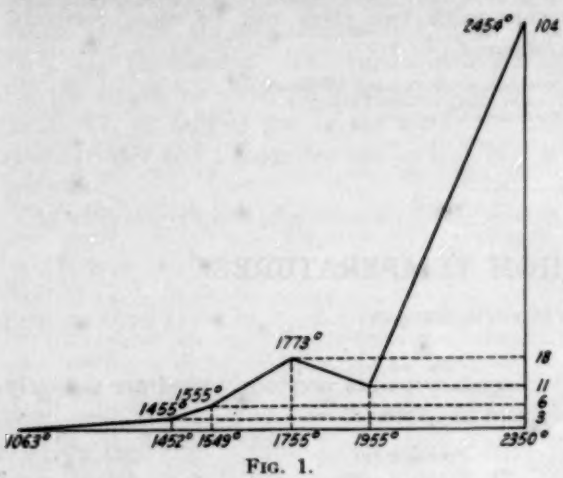

FIG. 1.

point for iridium at 2454 ± 3°C, making a comparison between gold and iridium and also a recheck between gold and platinum, and between platinum and iridium. Both methods arrived at the same value. Although this represents a very large (104°C) change from the older value, it should probably be accepted and previously estimated temperatures in this region should be adjusted upward accordingly.

Figure 1 shows graphically the increments that must be added to recorded temperatures, within the range covered, to bring them into agreement with these latest estimates. The correction between any two fixed points is assumed to be linear in character. This assumption can not be demonstrated, but inasmuch as pyrometric scales have previously been developed by linear interpolation between the fixed points as previously accepted, it is reasonable to expect that the corrections must also be uniform.

The same information is presented below in tabular form at intervals of 50°.

A number of temperatures to which frequent reference is made in ceramics, particularly in the field of refractories, must be revised in the light

TABLE I
TEMPERATURE COMPARISONS

Old (°C)	New (°C)	Old (°C)	New (°C)
1000	1000	1700	1715
1050	1050	1750	1768
1100	1100	1800	1817
1150	1151	1850	1865
1200	1201	1900	1913
1250	1251	1950	1961
1300	1302	2000	2022
1350	1352	2050	2083
1400	1403	2100	2145
1450	1453	2150	2206
1500	1504	2200	2268
1550	1555	2250	2330
1600	1609	2300	2392
1650	1662	2350	2454

of these points lately established. Several examples appear in the Al_2O_3–SiO_2 system:

	Melting point (°C)	
	Old value	New value
Al_2O_3–SiO_2 eutectic	1545	1551
Cristobalite	1713	1729
Mullite	1810	1827
Alumina	2050	2083

For pyrometric measurements, where more than comparative accuracy is desired, it will be necessary to have the calibrations of optical pyrometers revised. The changes are comparatively unimportant up to the limit of application of thermocouples and it is not likely that these recent findings should affect the calibration of thermocouples to any practical extent. Pyrometric cones in the higher numbers must also have new temperature intervals assigned to them.

It becomes an interesting matter for speculation as to whether the divergence from the older accepted values continues to increase above 2450°C. If this is true, much higher temperatures would need to be assigned to the melting points of the very refractory oxides, *e.g.*, CaO and MgO.

In addition to the International Critical Tables, from which the data on the older, fixed points were obtained, the authorities consulted were as follows:

(1) W. F. Roeser and H. T. Wensel, "Freezing Point of Rhodium," *Bur. Stand. Jour. Research*, **12** [5] 519–26 (1934); R.P. 676.

(2) F. Henning and H. T. Wensel, "Freezing Point of Iridium," *ibid.*, **10** [6] 809–21 (1933); R.P. 568.

(3) W. F. Roeser and H. T. Wensel, "Reference Tables for Platinum to Platinum-Rhodium Thermocouples," *ibid.*, **10** [2] 275–87 (1933); R.P. 531.

(4) W. F. Roeser, F. H. Schofield, and H. A. Moser, "International Comparison of Temperature Scales between 660°C and 1063°C, *ibid.*, **11** [1] 1–6 (1933); R.P. 574.

(5) W. F. Roeser, F. R. Caldwell, and H. T. Wensel, "Freezing Point of Platinum," *ibid.*, **6** [12] 1119–29 (1930); R.P. 326.

(6) H. T. Wensel and W. F. Roeser, "Freezing Point of Nickel as a Fixed Point on the International Temperature Scale," *ibid.*, **5** [6] 1309–19 (1930); R.P. 256.

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THE INTERNATIONAL STANDARDIZATION OF COLORS*

By A. Maerz

Abstract

Colors may be referred to by names or by systematic symbols. Of the latter, a number of systems has been proposed during the course of years, but none has ever found general or lasting acceptance. The reasons for this are brought out in an outline of the development of such systems and in an analysis and comparison of the whole group. A history of this kind has never been drawn up before and, without it as a background, the standardization of colors and of an accepted nomenclature can not be understood. The custom of referring to colors by names is examined in detail to determine whether a more systematic and standardized usage of names is not possible.

I. Introduction

It is impossible to understand what a standardization of colors means unless one has a knowledge of the history of ideas of color. It is indeed impossible even to understand the loose general way colors are regarded and named without a knowledge of this development. Fortunately, the steps are few, and are intimately connected. A few books like Ostwald's Farbenlehre or its English translation by J. S. Taylor, published in London in 1931, describe the systems of some of the earlier writers, but always in a disconnected manner and without realizing the logical development of color classification and nomenclature. Ostwald, for example, is interested only in criticizing the earlier systems as an argument in favor of his own.

In the present case, a short history of the conception of colors, their classification, and nomenclature, as a connected and related development, is to be presented. With this as a background, certain obscure details will become clear and a real basis for standardization will be apparent.

II. Pigment Mixture Differs from Light-Ray Mixture

The practice of decoration by colored pigments goes back into ancient times and so too does the knowledge of the results of mixing the so-called primary pigment colors, red, yellow, and blue. The ancient Greeks understood that pigment mixture was a different phenomenon from light-ray mixture. In the treatise on colors entitled De Coloribus, attributed to Aristotle, but now believed to have been the work of an unknown writer of the 4th Century B.C., it was said, "We must not proceed in this inquiry by blending pigments as painters do, but rather by comparing the rays reflected from the aforesaid known colors, this being the best way of investigating the true nature of color-blends." This statement has a quite modern sound, but that writer and the others of his day did not understand the real nature of the composition of white light from the various homogeneous rays. He stated that there were three "simple colors," white, black, and yellow, and that "from these primary colors the rest are derived in all their variety of chromatic effects by blending them and by their presence in varying strengths. Thus a dusky black mixed with yellow gives crimson."

It is astonishing to find a modern man, universally acknowledged to be one of the intellectual giants of history, Goethe himself, holding much the same theory, and vigorously combating the demonstrated truths of Newton's epoch-making experiments on light.

Aristotle, as all know, remained the great scientific authority for over a thousand years, but his caution, quoted above, was forgotten or never understood; the pigment (or painters') primaries were considered to be the only ones, and colors were believed to exist naturally in an order of five primitive kinds from light to dark, namely, white, yellow, red, blue, and black. Thus, Athanacius Kircher, in his book, Ars Magna Lucis et Umbrae, published in Rome in 1646, gave a diagram showing this order and the resulting mixtures, orange (which he called "aureus," that is, gold color), green, and purple.

III. History of Color Terminology

Newton discovered the correct theory of colors and gave, in *Opticks*, a diagrammatic representation of colors arranged in a circle. This paper was read before the Royal Society of London in 1675, first published in book form in 1704, and re-

* Presented at the Annual Meeting, American Ceramic Society, Buffalo, N. Y., February, 1935 (General Session).

printed by the McGraw-Hill Book Company in 1931.

Johann Tobias Mayer, a German mathematician, in lectures as early as 1758, but printed after his death,[1] presented a paper entitled "De Affinitate Colorum," which dealt only with pigments and their mixtures. He developed a system of nomenclature using the three color names, red, yellow, and blue, which he arranged in the form of a triangle, the pure colors at the angles, and the colors orange, green, and "purple" (as he called it), along the sides, in twelve gradations. In the center of the triangle was neutral gray, as would naturally result from the mixture of the three pigments. Mayer then graded this triangle of hues in four steps toward white and four toward black, and he thus had a complete system, which took the form of a prism.

Mayer was followed by Johann H. Lambert, who published Beschreibung einer Ausgemahlten Farbenpyramide in Berlin in 1772. Lambert altered Mayer's prism to a double pyramid.

Philipp Otto Runge, a young German artist, published his system in a small book in 1810,[2] in which he arranged all colors in the form of a sphere.

Newton, Mayer, Lambert, and Runge thus developed the foundations of everything that has been done by later writers, that is, the colors arranged in a circle, in a triangle, and in a sphere; white at the center, and neutral gray at the center. All succeeding work has been merely the alterations due to the personal preferences of individuals.

Had the development of color nomenclature gone on from this point undisturbed, probably the conditions today would be different. But unfortunately there appeared a writer whose works upset the possibility of an orderly classification and terminology for a long time and whose influence is still felt. This was George Field, whose book, Chromotagraphy, was issued in 1835. Field also wrote several other books, one of which, The Rudiments of the Painter's Art, or a Grammar of Colouring, first published in London in 1850, is still in print under the title, Grammar of Colouring, having gone through many editions.

[1] J. T. Mayer, Opera Inedita, pp. 33–42. Göttingen, 1775.

[2] P. O. Runge, Farbenkügel. Hamburg, 1810; reprinted in his collected works, Hinterlassene Schriften, Vol. I, pp. 112–28, 1840.

Field's follower, D. R. Hay, developed the idea of the numerical powers of colors extensively in his book, A Nomenclature of Colours, published in Edinburgh in 1845. The only matter of interest and the only reason for referring to him here is that it was Hay who first established the use of the terms "tint" and "shade" as they are used today.

This system of "primary," "secondary," and "tertiary" colors is totally erroneous, but it still has a wide popularity today and can be found in some of the latest books. Both Field and Hay chose to misuse the term, "purple," for the color, "violet," in spite of the fact that the term had been in correct use from ancient times and was commonly known.

A fourth landmark was reached when Forbes[3] in 1849 published a paper, "Hints toward a Classification of Colours." For the first time there appeared a comprehensive terminology. Forbes divided the spectrum and purples into twenty-four steps, that is, Newton's six hues, with three intermediate steps between each pair. He is the inventor of couplet-names (*i.e.*, "blue-green"), which many writers have followed since, with alterations to their own liking. Forbes' system was excellent of its kind, and had the succeeding authorities followed it, there would, perhaps, today be a universal terminology.

In 1864, the most celebrated perhaps of all color systems appeared, that of Chevreul, entitled Des Couleurs et de leur Applications aux Arts, Industriels à l'aide des Cercles Chromatique, published in Paris. Chevreul was a man of great scientific authority and enjoyed the support of the French Academy, but while his system was elaborately gotten out, was highly praised, and has been constantly referred to in literature, it never came into use.

In his nomenclature, Chevreul followed Forbes to the extent of using the list of names, red, red-orange, orange, orange-yellow, and so on. This gave twelve great divisions or groups, but he divided each further into six smaller steps, giving a spectrum range of seventy-two hues. These smaller or intermediate steps he numbered; thus, there was red, 1 red, 2 red, 3 red, 4 red, 5 red, red-orange, and so on. The range of a hue from white to black was in twenty-one steps, white being zero and black 21. The increments

[3] J. D. Forbes, *Philosophical Mag.*, Series 3, **34**, 161–78 (1849).

of gray added were known by fractions of tenths, $^1/_{10}$, $^2/_{10}$, $^3/_{10}$, and so on.

While Chevreul's system never came into use, his influence is found in every system since except that of Ostwald. The well-known system of Ridgway in this country followed it exactly. There is one feature in the Chevreul system which seems to be little known, for it is never mentioned in the references. Chevreul did not place his pure hues, that is, those of relative spectrum intensity, at an equal distance from the center on one certain circle. On the contrary, he placed the hues at different distances, yellow being nearer the center than blue, for instance. In this, he anticipated Munsell by half a century.

In Hamburg, 1877, appeared Otto Radde's International Farbenskala, an imposing title but a very poor work. His colored plates were merely reproductions of Chevreul's hue scales but were badly printed and without acknowledgment. He is entitled at least to this credit, that, for the first time, a systematizer realized that there was a greater range of hues in the yellow and blue-green than in the other parts of the spectrum.

About 1900 in Paris, Klincksieck and Valette issued their Code des Couleurs, using twenty-four of the seventy-two Chevreul hues, with one hue to a page. In 1905, the French work, Répertoire de Couleurs by Oberthür and Dauthenay appeared, prepared especially for horticulturalists, with each of 365 plates containing four tones of a single color, the colors being given names. None of these had much use, and they are really outside the line of development.

All of the above-mentioned works were European. The rest, except the German, Ostwald, are American.

In the 1890's, the two companies, Prang and Milton-Bradley began their great work of color education in the schools. In 1897, Prang published The Prang Standard of Colors, a beautifully lithographed book of color samples but with such an amazingly cumbrous terminology that it never came into use. It was soon abandoned in favor of one devised by D. W. Ross, thereafter found in the Prang books. This system followed the Chevreul list for the names of the hues, that is, red, red-orange, orange, orange-yellow, yellow, and so on; and it followed Chevreul in designating the grayed tones by fractions, here termed $^1/_4$, $^1/_2$, $^3/_4$ *intensities*. The scale from light to dark was called "white, high light, light, low light, medium, high dark, dark, low dark, and black. In the Milton-Bradley system of terminology for their colored papers, two steps were inserted between the six main groups, thus: red, orange-red, red-orange, orange, and so on regularly. Both of these two systems followed Chevreul in running the individual hue scales to white and to black.

In 1886, Robert Ridgway published A Nomenclature of Colors for Naturalists and, in 1912, a much enlarged edition called Color Standards and Color Nomenclature. Ridgway's system was a repetition of Chevreul's hues scales, except that he showed only seven color steps between white and black instead of Chevreul's twenty. Ridgway used thirty-six hues, half of Chevreul's seventy-two. The book was bought for the sake of the color samples it contained, but his system of initials was illogical and confused and was never used.

The Munsell system, issued first in 1915, under the title, The Atlas of the Munsell Color System, by A. H. Munsell, and re-issued in 1929 as The Munsell Book of Color, was that of Runge with features shown in Chevreul.[4] His terminology is illogical and complicated and is hard to hold in mind; moreover it does not permit of adjustment to an equal-sensation scale of hues, as Chevreul's simple system would have.

In the Munsell system, violet is called purple. Now this error of calling violet "purple," is an amazing one. For 2500 years, ever since ancient times, the two colors and names have been in use. Purple has always been the name for the color not shown in the spectrum, the color produced by the mixture of red and violet. Down through history, literature is full of references to it; yet there are people who apply the *name* "purple" to the *color* "violet." That anyone who has any knowledge of color can do this, passes comprehension.

Wilhelm Ostwald wrote a number of books on his system and published a Farbenatlas of color samples in 1918. Ostwald's system derives from Runge, except that instead of being a sphere, it is a double cone, the pure colors around the equator, as usual, and white and black at the two points.

These are the steps by which the present notions of colors and terminology have descended. The Maxwell-Rood triangle, now used with refinements in colorimetric computations, has not been included. This idea again goes back to

[4] See also A. E. O. Munsell, "Simple Method of Measuring Color," *Jour. Amer. Ceram. Soc.*, **6** [7] 777–82 (1923).

Newton.[5] Certain diagrams used in psychology, like the Benson and Titchener solids (merely a a refinement of Lambert's diagram, with four primaries instead of three), have not been included, as they are entirely aside from the present subject.

This brief history may be summed up in a very few words to give a complete vision of the whole matter. In the first step, Newton, in 1675, discovered the true relationship of colors and formulated practically everything in connection therewith. Mayer, in 1758, and Runge, in 1810, developed triangular and spherical solid diagrams. The rest is merely refinement. Chevreul, in 1864, placed the pure hues in a value-relation to the center of the chromatic circle. Ridgway followed Chevreul; Munsell and Ostwald followed Runge. For nomenclature, it was Newton who set up in correct order the list of names, red, orange, yellow, green, blue, violet, and purple. Forbes, in 1849, devised the couplet system, with red-orange, yellow-orange, etc.

IV. Arbitrary Terminology Not Popular

It is thus apparent that our present notions have come down to us through very few steps, which were very closely connected. And it is apparent also that from the first discoveries of correct relationship, very little, if anything, has been added. As a matter of fact, one could say that we have made little progress since the days of Newton, Mayer, and Runge. Some of the past systems enjoyed considerable popularity, yet are now forgotten and hardly known. Not one of them ever did have any real life or ever came into general acceptance or use. Why is this?

In the writer's opinion, after years of investigation, the reason for this failure is that people do not like arbitrary terminology for colors; they prefer names. If catalogues of ceramic colors are investigated, the *names* grass green, turquoise blue, delft blue, celadon green, and so on, are found. So it is in all industries; so it is likewise in the sciences. In Dana's Mineralogy, a standard work, the same names appear. From the most ancient times, mankind has taken a delight in colors and in bestowing names on them.

The Dictionary of Color[1] deals largely with names. It contains 7000 color samples, permanent to light and thus reliable as standards. Some 4000 names have been gathered in it, and in the Notes innumerable questions regarding colors and names have been answered. No colors were named arbitrarily. For example, in matching the ceramic colors included, the writer went to the great collection in the Metropolitan Museum of Art in New York and studied them at length. The work was laborious, time-consuming, and costly, but the results are authentic and may be depended on.

The solution of this problem has not yet been reached. The sad history of the past systems of arbitrary numerical nomenclature gives one no confidence in any of the current ones. As far as names are concerned, they have been standardized individually in the Dictionary of Color, which is available everywhere. It is in the *use* of these names that confusion exists, and it is here that systemization is needed.

From the writer's knowledge of the whole subject, the main trouble lies in the fact of that original division of the spectrum into six groups, red, orange, yellow, green, blue, violet, with the rejoining purple. These names in this order are impressed on us in early days at school and follow us all our lives. Yet they are in themselves so general that they are practically meaningless. A yellow may vary in hue from a very orange tone to a very green one. So with all the rest. And the couplets are just as bad, for a term like blue-green has very wide meaning. The only one solution is to abandon this list and make use of another, which represents the hues of the spectrum in conveniently small-step differences.

The reason is simple. It is one thing to look at a rainbow or a simple, un-magnified spectrum and observe that it seems to show only four, five, or six main hues; it is quite another to engage in the manufacture of colored articles to match critically the large range of colors used in industry.

It may be said that there are plenty of specific names by which to refer exactly to specific colors. True, there are thousands of them, though the Dictionary of Color[6] shows that they are unevenly distributed, many large ranges of color having no names at all, while for others numbers of duplicates exist. Nevertheless, at present, in trying to classify such colors, one is compelled to refer them to the old loose six-term division. If asked, for example, to describe the hue of celadon

[5] Maxwell, Scientific Papers, Vol. 1, pp. 121–22, 1890.

[6] A. Maerz and M. R. Paul, Dictionary of Color. 207 pp. 56 color pp. McGraw-Hill Publishing Co., Inc., New York, N. Y., 1930.

green, the best one can do is to say that it is a kind of blue-green, a description which is meaningless, for the range of different blue-greens is quite wide.

V. Proposed Classification of Colors

What is needed is to break up the so-called chromatic circle, that is, the whole range of hues, into as many groups as will be felt to be actually different, and to give distinctive names to these groups other than the wide general terms, red, yellow, blue-green, etc. These groups should show equal changes of hue. The names of these groups are not to be specific, but are to have a small tolerance of hue meaning, so that each will indicate a small group of closely related colors of a certain definite well-recognized kind. Thus each name would have a small leeway of application, a leeway which is absolutely essential in industry as well as in general usage, but which is thus known and standardized. It should be understood that this is not to advocate the abandonment of specific names, which are often required, or even to do away entirely with the use of the old general terms, which may sometimes be used for the most general indication of color where only a loose reference is needed. But the writer maintains from his experience with color troubles that, if such a list of names as this were adopted and really used, most of the color troubles would vanish.

Fortunately, a number of laboratory investigations has been made for the determination of least differences in hue discrimination. From these data, a curve can be drawn showing color sensation changes, the hues being designated by wave-lengths. From this curve, the spectrum may be divided into as many steps as needed, the steps representing equal differences in hue. The writer uses the curve published by Nutting,[7] as he was the first to propose such a curve, later investigations merely confirming his work. The wave-lengths of these steps being known, anyone in the world can reproduce them any time.

A long series of studies and experiments have convinced the writer, keeping in mind always practical industrial necessities, that the chromatic circle is most conveniently divided into about eighteen steps. These steps should be known by names. For this work, a list of names was selected, the initial letters of which would include no duplicates and further would not make use of the initials of the old general terms, red, yellow, green, blue, and purple. Thus in many cases for record, the initials alone could be used with much saving of space, and, moreover, this system could be used, as initials, without confusion with the old six-term list of general names.

The desire naturally was to use such names as were exceedingly well known, in general use, and in correct use. A number of such names, like turquoise, was available. It was found, however, that a few of the hues had never been given names, strange as it may seem. These were the red at the end of the spectrum; greenish-yellow; the two steps between the latter and emerald; and the next bluer green beyond emerald. The writer tried to find names for these from natural objects, and spent days at the American Museum of Natural History and the Metropolitan Museum of Art in New York, and had some of the curators there also working on this problem, but without success. There are no objects in nature which show these hues in pure bright tones. It should be remembered that the names must be absolutely simple, sane, pleasant sounding; not couplets and not technical. After listing the initials of the names like turquoise (T), scarlet (S), emerald (E), and so on, which must appear in the system, there was left only D, H, J, N, X, and Z, for W must be kept for white and the initial, I, is sometimes used for the old Newtonian term, indigo, and moreover is too easily mistaken for the number 1.

The writer therefore had to draw names from other sources, names which had no direct association with colors. Lack of space prevents telling of the difficulties this job brought, but the list of names is given. The point that these names are not to be regarded as indicating *specific hues* must be emphatically stressed. They must be considered as possessing a *small tolerance of hue.* After each, is given its reference in the Dictionary of Color,[6] which shows the approximate middle hue of the small tolerance.

Crimson 360	1 F 6	Emerald 515	25 E 12
Magenta 375	41 L 2	Dragon 534	17 L 11
Amaranth 390	41 L 7	Zanadu 554	17 L 8
Violet 427	41 L 10	Hyperion 568	17 L 4
Quirinal 444	41 K 12	Lemon 580	9 L 3
Ultramarine 462	41 C 12	Orangepeel 592	9 L 9
Kobalt 478	33 L 11	Flame 608	1 C 12
Turquoise 490	33 L 2	Scarlet 632	1 K 12
Juniper 502	25 L 8	Noel 606	1 L 6

Wave-lengths in millimicrons are given after

[7] *U. S. Bur. Stand. Bull.*, Vol. 6, No. 1 (1909).

the names. It will be noted that the wavelengths of the purplish and crimson hues are stated in the three-hundreds, which are below the visual band. In technical fields, it is customary to specify these in terms of their complementaries, that is, the colors with which when mixed form white. This practice is somewhat confusing, and a new method is here followed of specifying them in terms of their lower "octave," which is just as legitimate for reference purposes and has the advantage of not duplicating the numbers of the greenish hues and of forming a continuous series. The *name* "violet," is here retained, as the *hue*, violet, is so restricted that no confusion is possible. The hue, orange, also is restricted and the name should be a quite close one, but the name has become very loose, being applied to colors that are actually true scarlets; it first meant the color of the orange peel and should still; therefore the term "orangepeel" is used here and the initial, O, is kept, for eventually the proper usage will return and the initial will not then have to be changed. Kobalt is spelled with a "K," as "C" simply must be left for crimson; it was thus originally spelled and still is in European languages.

An important point to be stressed is that the general terms are *not* to be added after any of these names; we want to avoid precisely this practice. We must say "emerald" and not "emerald green." Thus these names will themselves possess strict color meaning and not be merely qualifying indicators added to the loose general terms.

In the philatelic weekly, *Stamps*, beginning October 6, 1934, issue, the writer presented a series of articles, with further notes in January 12, 1935, which went more fully into the matter. The covers of this well-known magazine are being printed each week in a different color, according to this system, which will take a year to complete.

It has frequently been proposed in the past that color-mixers could do all their work with but three fundamental colors, a red, a yellow, and a blue, but such systems are impractical and are put forward by impractical men. The intermediate hues can be produced by mixture, but they lack the purity and brightness of the primaries. Nor is there any necessity whatsoever that anyone should restrict himself to three. It is easy to go to the opposite extreme and use far too many. This has always been a custom in the past and still is, with exceptions. One such exception is the outfit put out by the Sherwin-Williams Company in their Opex Slide-Rule Color Match Guide for the special benefit of automobile finishers. With the Color Match Guide comes fifteen colors including white and black, and these, in the exact mixtures indicated by the Guide, produce a correct color match to any desired shade. This Guide, is sold in the complete outfit and not distributed gratis. The Sherwin-Williams Company deserves high praise for it.

The names applied to the colors in the Sherwin-Williams outfit are naturally those of the painter's pigments, like chrome yellow. In the system outlined above, the names are entirely nontechnical in nature and are intended solely to indicate color sensations. Such names are preferable, except for purely technical reference, as color sensations like turquoise or scarlet are the same in all industries, no matter what substances produce them, whether ceramic, paint, or dye.

VI. Summary

To sum up, then, the classification and nomenclature of colors has been based upon arbitrary numerical systems, invented by a certain few individuals. Some elaborate systems have been published and acclaimed, only to fall into obscurity, without practical use or acceptance. It has been established that people prefer names for colors, even in the industries and sciences. The names for colors have mounted into the thousands, still increasing, but without regard to system, with all sorts of troubles accompanying them, confusions, errors, financial losses. If that is so, and everyone knows that it is, it would seem to be time that someone took the systemization of the usage of color names in hand.

Such standardization should be international. A hundred years ago, in acoustics, there was just as great confusion, but agreement was finally reached and today there is an international standard of pitch, which all manufacturers of musical instruments follow. So also today in many other fields of science and industry there are international standards. So in the domain of color there should be one, for colors today touch the financial interests of manufacturers very closely.

EDITOR'S NOTE: Additional information on this subject was presented in *Bull. Amer. Ceram. Soc.*, **14** [10] 349–53 (1935).

AMERICAN COLOR RESEARCH LABORATORY
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CERAMIC ABSTRACTS[1]

Compiled by the
AMERICAN CERAMIC SOCIETY

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Abrasives

Blast melting of bauxites for the alumina industry. Anon. *Metallurg*, **10** [5] 86–89 (1935). S.I.P.

Grinding and polishing aluminium and its alloys. A. von Zeerleder. *Aluminium*, **17** [5] 245–51 (1935); *Bull. Brit. Non-Ferrous Metals Research Assn.*, No. 78, p. 5 (July, 1935).—A detailed practical account is given.

Grinding and polishing compositions. Rudolf Plucker. *Allgem. Oel- & Fett-Ztg.*, **32**, 103–107 (1935); *Chem. Abs.*, **29**, 4911 (1935).

Investigations of synthetic millstones. R. Simpson. *Fed. Paint & Varnish Production Clubs, Official Digest*, No. 145, pp. 160–62 (1935); *Chem. Abs.*, **29**, 4215 (1935).—Aloxite millstones can be dressed more accurately and are more efficient and economical than buhrstones.

New Hampshire garnet deposits. Louis C. Conant. *Econ. Geol.*, **30** [4] 387–99 (1935).—For several years New Hampshire has been second only to New York in the production of abrasive garnet. The active quarry at North Wilmot (Merrimack County) consists of rock containing about 50% almandite garnet ($Fe_3Al_2(SiO_4)_3$). In Danbury there are smaller deposits which have been worked in the past. Several unexploited deposits have good economic possibilities. C. describes the occurrence of the ore and associated rocks and discusses the origin of the ore and the geologic history of the deposit. Physical and chemical properties of the garnet are given together with two chemical analyses. One photomicrograph. J.L.G.

Polishing aluminum castings. Fred B. Jacobs. *Metal Cleaning & Finishing*, **7** [8] 389–90 (1935).—Factors governing wheel selection for polishing aluminum, in reality an alloy, are discussed. Five abrasives used for this purpose, Turkish, Naxos, and American emery, natural corundum, and manufactured alumina, are described as to occurrence, chemical composition, and grit size best suited for polishing. Proper operating speeds for polishing operations are given. E.J.V.

Books

Abrasives. Edited by A. E. Fersman, *et al.* See *Ceram. Abs.*, **14** [10] 237 (1935). **Determining the crystalline aluminium oxide in corundums and emeries.** L. I. Ignatova. Pp. 92–98. The chemical and mineralogical analyses of corundums and emeries are given. The methods of chemical and mechanical analyses are outlined. **Corundum "minutniki."** O. A. Sokova and O. V. Almazova. Pp. 99–106. "Minutniki" is the name for thin corundum powders used for abrasive purposes. Their name is derived from the time (in minutes) necessary to separate off every number of "minutniki" in a column of still water from a thin, previously dispersed, abrasive material. S. I. Perkal

Mineral Raw Materials in Industry. I. Grinding and Polishing Materials. N. Fedorovskiĭ. Verlag "Gorisdat," Moscow, 1932. 107 pp. Price 1.50R. Reviewed in *Referatkartei Silikatliteratur*, No. 423 (1934).—The properties, uses, and working of natural and artificial abrasives, such as diamond, corundum, ruby, emery, emerald, garnet, rock crystal, quartz, quartzite, diatomaceous earth, pumice stone, grindstone, silicon carbide, and other carbides, etc., are described in detail. M.V.C.

Patents

Abradant. Georg Kränzlein and R. K. Müller (I. G. Farbenindustrie A.-G.). U. S. 2,013,496, Sept. 3, 1935 (April 13, 1932). An article of manufacture comprises a grit or layer of abrasive particles and an adhesive bond for uniting the abrasive particles to form a coherent mass or layer, the bond including a hardened resinous condensation product of a polyhydric alcohol with a mixture of a polybasic acid from a fusible synthetic resin and a fatty acid of at least 10 carbon atoms.

Abrasive wheel. R. C. Benner and H. E. Stowell (Carborundum Co.). U. S. 19,678, Aug. 27, 1935 (July 9, 1935); reissue of original, U. S. 1,982,628, Dec. 4, 1934.

Adjusting devices for the abrasive elements of grinding machines. A. A. Thornton (Bertoni & Cotti). Brit. 429,799, June 19, 1935 (March 22, 1934).

Art of grinding. G. W. Binns (Cincinnati Grinders, Inc.). U. S. 2,012,078, Aug. 20, 1935 (Feb. 7, 1931).

Crank-shaft grinding machine. C. H. Amidon (Norton Co.). U. S. 2,012,263, Aug. 27, 1935 (Sept. 19, 1934).

Cutting and grinding disk for natural and artificial

[1] The bold-face number following the journal is the volume, the issue number is in brackets, followed by the page numbers, then the year in parentheses.

stones, etc. E. L. W. BYRNE (United Carborundum & Electrite Works Co.). Brit. 429,706, June 19, 1935 (April 12, 1934).

Disk grinding machine. F. M. HARGRAVE. U. S. 2,014,327, Sept. 10, 1935 (July 2, 1934).

Flexible abrasive coated articles and the manufacture thereof. CARBORUNDUM CO., LTD. Brit. 433,880, Sept. 4, 1935 (Feb. 22, 1934).

Grinding or abrading machines. F. H. LLOYD & Co. AND W. DUDLEY. Brit. 433,882, Sept. 4, 1935 (Feb. 27, 1934).

Grinding machine. M. H. ARMS (Bryant Chucking Grinder Co.), U. S. 2,013,122, Sept. 3, 1935 (Nov. 8, 1932). H. L. BLOOD AND A. P. BURNS (Heald Machine Co.), U. S. 2,011,705, Aug. 20, 1935 (July 20, 1933). F. S. HAAS AND R. L. GOETZEL (Cincinnati Grinders, Inc.) U. S. 2,012,065, Aug. 20, 1935 (May 31, 1930). G. F. WILSEY, U. S. 2,013,262, Sept. 3, 1935 (Aug. 30, 1933).

Headstock for machine tools. F. S. HAAS AND E. D. VANCIL (Cincinnati Grinders, Inc.) U. S. 2,012,066, Aug. 20, 1935 (March 3, 1934).

Method and apparatus for manufacturing abrasives and the abrasives resulting therefrom. MINNESOTA MINING & MFG. CO. Brit. 433,128, Aug. 21, 1935 (March 23, 1933).

Method of grinding worms and screws. NIKOLA TRBOJEVICH. U. S. 2,011,956, Aug. 20, 1935 (July 7, 1930).

Polishing, burnishing, or stropping of safety-razor blades. V. R. CAM. Brit. 433,476, Aug. 28, 1935 (Feb. 27, 1934).

Polishing machine. L. E. WOOLENS (General Spring Bumper Corp.). U. S. 2,013,196, Sept. 3, 1935 (May 20, 1931).

Reversing mechanism for machine tools. W. F. FRASER (Norton Co.). U. S. 2,012,273, Aug. 27, 1935 (Aug. 27, 1928).

Roll-grinding machines. NORTON CO. Brit. 433,114, Aug. 21, 1935 (Dec. 4, 1933).

Shaping the operative surfaces of the grinding and control wheels of centerless grinding machines. F. G. HEARD. Brit. 432,285, Aug. 8, 1935 (Jan. 26, 1934).

Sheet abrasive and method of making. F. G. OKIE (Minnesota Mining & Mfg. Co.). U. S. 2,013,925, Sept. 10, 1935 (Feb. 6, 1929).

Art and Archeology

Architects of Europe today. No. 4. Gio Ponti, Italy. GEORGE NELSON. *Pencil Points*, **16** [5] 215–22 (1935).—N. describes the work of Gio Ponti, including ceramics, and expounds his theories of design and materials. E.B.H.

Art evolution in British pottery. ANON. *Pottery Gaz.*, [698] 985–86 (1935).—An exhibition at the Victoria and Albert Museum, Kensington, illustrating the development of art in relation to pottery manufacture is described. E.J.V.

Exhibition of Bernard Moore pottery. ANON. *Pottery Gaz.*, **60** [698] 992–93 (1935).—Over 400 examples of Moore's work were shown at Stoke Town Hall. Illustrated. E.J.V.

Pottery design moving toward modernistic. FREDERICK H. RHEAD. *Ceram. Ind.*, **25** [3] 123 (1935).—A gradual swing from Victorian styles to modernistic designs in tableware is noted. Tableware lines are being extended into the ovens so that kitchenware is becoming more ornamental and decorative. E.J.V.

Sculpture in pottery. MARIE PETRIE. *Pottery Gaz.*, **60** [698] 1003–1005 (1935).—The potter's art is closely related to the branch of the sculptor's art of building up out of a soft material. Ceramic statuary is a mixed art, standing in much the same relationship to sculpture as does relief modeling. Many useful pointers to would-be sculptors in pottery are given by the author, who has had experience in the modern field of sculpture. E.J.V.

BOOK

Design. NOEL CARRINGTON. (Twentieth Century Library.) John Lane, The Bodley Head, Ltd., London, 1935. 140 pp. Price 3s 6d. The parts played in modern design by the industrial designer, the manufacturer, the distributor, the individual, and the State are defined. Illustrated. H. H. STEPHENSON

PATENTS

Designs for:

Cooking stove. M. G. KLEMME (Eagle Foundry Co.). U. S. 96,842, Sept. 10, 1935 (June 24, 1935).

Cup. VINCENT BROOMHALL AND H. A. SMITH (Salem China Co.). U. S. 96,722, Sept. 3, 1935 (March 4, 1935).

Glass tumbler. GEORGE DOUGHERTY (Morgantown Glass Works). U. S. 96,731, Sept. 3, 1935 (July 3, 1935). J. G. FUNFROCK (Morgantown Glass Works). U. S. 96,737, Sept. 3, 1935 (July 3, 1935).

Gas range. D. L. HADLEY (Tappan Stove Co). U. S. 96,746, Sept. 3, 1935 (March 30, 1935).

Pitcher. E. W. NEWTON (Imperial Glass Corp.). U. S. 96,623, Aug. 20, 1935 (July 11, 1935).

Range base. D. L. HADLEY (Tappan Stove Co.). U. S. 96,747, Sept. 3, 1935 (April 9, 1935).

Tumbler. E. W. NEWTON (Imperial Glass Corp.). U. S. 96,622, Aug. 20, 1935 (May 4, 1935).

Method of preparing outlines of designs. ANDRÉ SCHOEN (Reconstruction Finance Corp.). U. S. 2,013,010, Sept. 3, 1935 (July 11, 1931). A method of forming an outline of a design comprises forming a bleached and hardened image of the subject on a sensitized medium comprising a silver halide emulsion, applying a resist which adheres only to the hardened portions of the image, immersing the resist-covered image in a developing solution, which penetrates and diffuses in those portions of the gelatin which were not exposed during the production of the image, contacts with the edges of the image, and diffuses in the image, whereby the image is developed at those portions contacting with the developer, and removing the resist and undeveloped portions of the image.

Cements

Analyzing Portland cement kiln clinker burning operation. H. O. O'Neill. *Western Gas*, **10** [1] 14 (1934).—Graphs and tables give details of fuel consumption, flue-gas analyses, carbon dioxide obtained from lime in slurry, and a heat balance in B.t.u.'s per pound of natural gas. J.M.K.

Plaster of Paris in dentistry. R. N. Johnson. *Brit. Dental Jour.* (reprint), **56**, 10 pp. (March 15, 1935); *Brit. Chem. Abs.*, **54** [29] 631*B* (1935).—The constitution of plaster and the mechanism of its setting (*S*) are briefly described, and the effect of plaster to H_2O ratio, time of mixing, and temperature on *S* time, expansion (*E*), hardness, and strength has been studied. Certain salts, *e.g.*, KCl, K_2SO_4, increase the *S* rate and decrease *E*, while others, *e.g.*, borax, retard *S* and diminish *E*. By the suitable admixture of the two types of salt the plaster may be modified to suit the making of both the impression and the model. The preparation of these retarded and accelerated anti-expansion (*A–E*) solutions is described in full. The S rate of plaster decreases with storage, even in a closed container. These variations are best overcome by maturing the plaster by exposing it in thin layers to the atmosphere for a few days. The use of the retarded *A–E* solution gives a mold which has a greater resistance to the destructive action of steam treatment during the vulcanizing process. Hints are given for the accurate temperature control of the vulcanizer. The decomposition of the plaster and the consequent deterioration (including contraction) of the mold during dry heating (in drying off and resin molding) are discussed. The best medium for separating the mold and impression is prepared by adding an equal volume of sperm oil to a jelly of Castile soap in H_2O. The separation of the vulcanite denture is facilitated by painting the mold with cellulose acetate solution ("Cellace").

Setting of Portland cement. Chemical reactions of seasoning, reversion, and restoration. P. S. Roller. *Ind. Eng. Chem.*, **26** [10] 1077–83 (1934).—The changes in setting and in the amount and composition of the liquid phase of six normally gaged clinkers have been investigated in relation to exposure of the clinkers to water-vapor and carbon dioxide. The clinkers behaved in the same way qualitatively and in some respects quantitatively. Direct evidence exists for activation by absorbed water-vapor both of tricalcium silicate and tricalcium aluminate; de-activation by absorbed carbon dioxide is assumed on reasonable grounds. The present experimental evidence indicates the existence of such activation and de-activation of tricalcium silicate and tricalcium aluminate in Portland cement. Taking the effects into account, the action of absorbed water-vapor and of carbon dioxide on the setting of Portland cement is satisfactorily explained. Illustrated. F.G.H.

Study on gypsum. Kawatake Tone. *Repts. Imp. Ind. Research Inst., Osaka* [Japan], **15** [6] 1–56 (1934); *Chem. Abs.*, **29**, 572 (1935).—Dehydration of $CaSO_4 \cdot 2H_2O$ begins at 70° and becomes $CaSO_4 \cdot {}^1/_2H_2O$ (I) at 73°, then anhydrous $CaSO_4$ at 105 to 110°. The latter takes up moisture from air and becomes I. The anhydrous compound obtained at 400° or above does not take up moisture from air. The higher the temperature of calcination of gypsum ores, the smaller will be the amount of H_2O required to bring the gypsum into plastic condition and the longer will be the time of solidification, while the resistance to breakage by pressure of the resulting solid increases with the rise in temperature of calcination. The finer the powder, the smaller is the amount of H_2O necessary to bring gypsum into plastic condition and the shorter becomes the time of solidification, while the resistance to breakage increases. The gypsum which has been calcined at higher temperatures (above 400°) and which does not become I in air can be made into a high-pressure resisting solid if the spontaneous evaporation of moisture is prevented during solidification by leaving the sample in a moist chamber. The addition of salts shortens solidification time but decreases the mechanical quality. A powerful dehydrating substance can be obtained by mixing $CaCl_2$ solution with burned gypsum.

PATENT

Cementitious composition of matter. L. L. Cailloux. U. S. 2,013,132, Sept. 3, 1935 (Aug. 2, 1933). A composition of matter includes magnesia 1 part, talc $^1/_{10}$ to $^1/_{20}$ of a part, silica sand $^1/_2$ to $3^1/_2$ parts, and a 16 to 25° Bé solution of magnesium chloride including from $^1/_{10}$ to $^1/_{60}$ the magnesium chloride weight of barium chloride.

Enamel

Acid-resistant enamels. H. Lang. *Glashütte*, **65** [23] 349–50; [24] 361–63 (1935); abstracted in *Verre & Silicates Ind.*, **6** [13] 246 (1935).—The silica content of acid-resistant enamels must be high and over 50%. The choice of fluxes is important. Borax must be eliminated and replaced by a mixture of carbonate, phosphate, and sodium sulfate which is a less energetic flux than borax. Quartz may be replaced by ground glass which is much more fusible. For chemical resistance, titanium, lithium, and cerium oxide are good; they are also excellent opacifiers. Cerium oxide (1 to 2%) gives a greater luster than borax. For enamels resistant to weak acids, up to 15% borax is permitted. Antimony can be used as opacifier, but not cryolite. The enamels should be somewhat less finely ground. Additions to the mill: 3 to 6% clay or 0.5 to 1% ultra-ocher, 0.25 to 0.5% ammonium alum, 0.5 to 1% soda. Tin oxide can be advantageously replaced by cerium in spite of its high price. Often anti-acid enamel is not applied to sheet iron until the third coat. On cast iron, the fritted mass is applied by the wet method, then the anti-acid; or the fused mass is powdered, then the anti-acid. These enamels require hotter firing than ordinary enamels. M.V.C.

Acid-resisting enamels. Ludwig Stuckert. *Chem. Markets*, **33** [3] 238–39 (1935).—So far the production of enamel linings highly resistant to acids has been com-

pletely successful only with cast iron. This is due largely to the fact that the cubical coefficient of expansion of cast iron lies nearer to that of the enamel employed than does the coefficient of sheet iron. It has been found possible to line sheet iron with a relatively acid-resistant enamel, but the corrosion resistance in this latter case is by no means equal to that obtained in the case of cast iron. The enamel must be so chosen as to possess a certain degree of elasticity. In general, the resistance to acids of these enamels increases with their rising content of silicic acid, but this is not a linear relationship. The influence of basic oxides generally follows the affinity which those bases have in the free state for both water and acids, and sesquioxides, such as alumina, are consequently valued ingredients of highly acid-resisting enamels. Since the solubility of the salts which may be formed by the attack of the acids is another point in the selection of enamel ingredients, sodium fluoride and cryolite should be excluded. As little clay as possible should be used since clay lowers the chemical resistance of these materials. Tables of typical compositions are given. Further points to be observed are the adequate fineness of grinding of the raw materials, their intimate admixture, and the uniform fusion of the enamels at a high temperature. The preliminary surface treatment of the iron before enameling is important. A description of the firing and cooling operations is given. M.J.H.

Best results with the dipping process. ANON. *Ceram. Ind.*, **25** [3] 140–42 (1935). E.J.V.

Cleaning cast-iron parts for porcelain enameling. ANON. *Better Enameling*, **6** [8] 14–18 (1935).—Illustrated. E.J.V.

Color stability in enamels. WILLIAM J. BALDWIN. *Jour. Amer. Ceram. Soc.*, **18** [10] 321–22 (1935).

Control of the physical properties of enamel. M. G. AMMON. *Emaillerie*, **3** [5] 9 (1935); abstracted in *Verre & Silicates Ind.*, **6** [12] 230 (1935).—A modern laboratory for testing the quality of enamels and their resistance to the action of atmospheric agents, resistance to thermal shock, abrasion, and impact, and their adherence, hardness, coefficient of expansion, and opacity is described. M.V.C.

Cooling of enamels. A. DIETZEL AND K. MEURES. *Sprechsaal*, **68** [22] 339–41 (1935).—Systematic cooling tests with a ground enamel and sheet iron showed that the most favorable cooling zone for coated sheet iron lies between 200 and 300°. The release of tensions in enamel can not be explained by processes similar to the cooling of glass. Expansion tests on sheet iron from room temperature to 500° demonstrated that during cooling the iron is equal to the enamel (through expansion or compression) and in that way makes possible a far-reaching equalization of tensions. M.V.C.

Discussion on thermal expansion methods from theoretical and practical standpoints. C. J. KINZIE AND C. H. COMMONS, JR. *Jour. Amer. Ceram. Soc.*, **18** [10] 306–308 (1935).

Enamel cleaner marketed. FERRO ENAMEL CORP. *Enamelist*, **12** [11] 15 (1935). E.J.V.

Estate Stove pioneers. ANON. *Amer. Enameler*, **7** [10] 3 (1935).—The Estate Stove Company was among the first to use enamels. H.T.

Fineness distribution of vitreous enamel as affected by variations in grinding. E. P. POSTE. *Jour. Amer. Ceram. Soc.*, **18** [10] 303–305 (1935).

Graining and care of composition rollers. ANON. *Amer. Enameler*, **8** [5] 3 (1935).—The composition of rollers (glue and glycerine) is sensitive to moisture and temperature, especially when new. Rollers should never be put into service until they have been aged for at least ten days. When not in use, they should be coated with a good grade of motor oil and placed in a warm, dry atmosphere. Temperatures in excess of 125°F will melt the roll and throw it out of balance. Any good naphtha thinner with about 15% S.A.E. 20 paraffin oil added is said to be an excellent cleaning medium for composition rollers. After each print, the roll should be wiped clean with a cloth previously dampened with an oil thinner mixture. Viscosity and consistency are factors exercising great influence on the strength and shade of the print. Fineness in a color oxide is paramount. Unfired enamel to be grained must be absolutely dry. H.T.

Heat-treating and enameling industries produce sanitary ware. J. B. NEALEY. *Ind. Gas*, **13** [6] 19 (1934).—Frit smelting and enameling operations at the U. S. Sanitary Mfg. Co. are described. The semi-muffle type gas-fired furnaces are equipped with automatic temperature control. Illustrated. J.M.K.

Investigation of some physical factors affecting the draining qualities of ground-coat enamels. W. N. NOBLE AND G. S. LINDSEY. *Jour. Amer. Ceram. Soc.*, **18** [10] 308–14 (1935).

Layout of enameling plant equipment. S. M. STOLER. *Amer. Enameler*, **7** [10] 5 (1935).—A report presented by the Management Division of the A.S.M.E. states that manufacturers are scrutinizing more carefully their plant layouts to reduce that overhead which comes from the manner of processing their products through the plant. H.T.

Magnetic separator. ANON. *Amer. Enameler*, **8** [5] 4 (1935).—S. G. Frantz designed an efficient apparatus to remove iron from slips, glazes, and slurries. The removal of these fine impurities results in a marked lightening of the shade of the finished body. H.T.

Mechanics of enamel adherence. XI. Application of the theory of dendritic adherence to the development of white ground coats for sheet steel. W. L. HOUSLEY AND R. M. KING. *Jour. Amer. Ceram. Soc.*, **18** [10] 319–20 (1935); for Part X see *Ceram. Abs.*, **13** [8] 201 (1934).

Metal decorating oven incorporates unique features. R. BYRON. *Ind. Heating*, **2** [8] 429–34 (1935).—A furnace for decorating by enameling or otherwise coating or finishing metals under controlled heat and atmospheric conditions is described. M.H.

Methods to improve the quality of Monarch ranges. L. W. WEIMER. *Ceram. Ind.*, **25** [3] 127–28 (1935).—Increased business forced the installation of a new furnace at the Malleable Iron Range Co., Beaver Dam, Wis. The new box-type, double-fork furnace has a combustion chamber 6 ft. wide, 12 ft. long, and 6 ft. 7 in. deep, with a bridge wall running through the center. More uniform firing is secured by this design with no trouble of overfiring. A 50-ft. tunnel drier is used for drying cast-rion pieces. A 50–50 mixture of steel grit and sand is used in

sandblasting. The floor and certain sections of wall are vacuum-cleaned every night, insuring a dust-free and clean condition. Illustrated. E.J.V.

Mill room control. G. H. SPENCER-STRONG. *Amer. Enameler*, **8** [1] 3 (1935).—In the mill room, quick, simple checks, tests, and records should be used. If the mill foreman has a complete record of the performance of the mill, he can operate it more accurately. A production test should be made on each mill before it is put into use. The screens should be tested against a standard. S. shows blank forms that would serve to provide a complete mill-room record. H.T.

Multi-color enameled signs help chain-store advertising. R. H. MINTON, JR. *Ind. Gas*, **13** [12] 6 (1935).—Copper is used as the base in making enameled letters for signs. The letters are boiled in a cleaning solution and dried. The hollow backs are filled with sprayed enamel. The face of the letters is covered by the dry enamel process known as dusting. Care must be taken that air bubbles in the enamel do not break through during the fusing. The success in firing the enamel depends on the proper relation of time and temperature. Fair results with plain whites may be had with temperatures ranging from 1525 to 1650°F. The range for various colors is quite narrow. The time ranges from $7^1/_2$ minutes on some whites to 90 seconds on certain colors. Loads of finished ware are turned out at an average of once every 7 min. This is considerably better than ordinary practice and is due partly to careful scheduling of work and partly to the use of a gas-fired muffle furnace. J.M.K.

Necessity of testing mill additions. P. C. STUPPT. *Amer. Enameler*, **7** [2] 5 (1935).—Various materials are added to the mill to produce certain desirable effects and each material has its individual duty to perform. Since the increase or decrease of one material will change the desired quantity of other materials, proper control of the mill formula should be exercised. Clays frequently contain foreign materials which will cause black specks in the finished enamel. Soft water should be used in the mill formula. Borax contains about 47% water of crystallization and, if stored for an appreciable length of time, some of the water will be lost. Magnesium carbonate is not affected by storing as long as it is kept free from dirt. A simple test for the presence of foreign material in clay is given. H.T.

Opacity development in cover enamels for sheet steel. JAMES D. TETRICK. *Jour. Amer. Ceram. Soc.*, **18** [10] 314–18 (1935).

Oxides for graining porcelain enamels. D. B. NOLAND. *Amer. Enameler*, **8** [2] 5 (1935).—Oxides for graining should be fired in conjunction with the enamel. Color oxides for graining purposes must pass a 300-mesh sieve. They should be absolutely dry, if a good working paste is to be expected. It is difficult to obtain an oxide that will fire out properly on both sheet steel and cast iron and still match. Excellent results have been obtained by mixing two oxides of the same color but of different hardnesses. H.T.

Porcelain enamel for washing machines. W. W. GALBREATH. *Amer. Enameler*, **8** [1] 4 (1935).—Enamel was introduced as a part of the washing machine as a result of the advance in the price of copper which was being used in the tub. Today there is only one manufacturer who does not use the enameled tub. H.T.

Resistance to heat of enameled vessels. W. DAWIHL. *Keram. Rund.*, **42**, 474 (1934); *Chem. Abs.*, **29**, 309 (1935).

Setting enamels with hydrochloric acid. FRANZ NOVAK. *Amer. Enameler*, **8** [2] 4 (1935).—Hydrochloric acid is recommended as a setting-up agent for acid-resisting and stainless enamels because of its uniform reaction. It has been found necessary to standardize the amount of acid used, as it has a definite effect on certain colors. It was determined that 1 cc. of hydrochloric acid per pound of liquid enamel would give the best results. The substitution of ammonium carbonate for potash alum in the mill formula made it possible to grind all sheet-iron, cast-iron, acid-resisting, and stainless enamels to a fineness of 10% (Amer. Ceram. Soc. Standard) without encountering settling. A fixed quantity of acid is then added to improve the workability and richness of color. H.T.

Sodium nitrate. G. H. MCINTYRE. *Enamelist*, **12** [11] 24–25 (1935).—Sodium nitrate, while used in relatively small quantities in porcelain-enamel frit manufacture, is important because it is a strong oxidizing agent. The sodium nitrate of commercial use is obtained almost entirely from the arid regions of northern Chile. The crude ore contains 25 to 50% sodium nitrate, which is leached with hot water to yield approximately 95 to 98% pure sodium nitrate. Various theories as to the sources of the nitrate deposits are discussed. E.J.V.

Study of furnace atmospheres and temperature gradients and their effect on porcelain enameling. H. E. EBRIGHT, G. H. MCINTYRE, AND J. T. IRWIN. *Jour. Amer. Ceram. Soc.*, **18** [10] 297–302 (1935).

Swinging arm spray coating machine. DEVILBISS CO. *Enamelist*, **12** [11] 18–19 (1935).—Illustrated. E.J.V.

Use of sodium cyanide in a neutralizing bath in pickling sheet iron for enameling. E. H. SHANDS, G. L. BRUTON, AND G. J. GRIMES. *Jour. Amer. Ceram. Soc.*, **18** [10] 323–24 (1935).

Vitreous enameled iron. ANON. *Chem. Trade Jour.*, **95** [2472] 237–38 (1934).—A short history of the enameling industry in England is given. H.K.

Vitreous enameled iron and stainless steel in architecture. M. J. R. MORRIS AND KARL KAUTZ. *Amer. Enameler*, **8** [4] 5 (1935).—Vitreous enameled iron has many advantages. H.T.

Widening the neck of the bottle. S. M. STOLER. *Amer. Enameler*, **8** [4] 3 (1935).—It is possible to increase the output of the old box-type enameling furnace as much as 100% with a maximum investment of 25% of the cost of a new furnace. This is accomplished by redesigning the firing tools, the ware being hung from "S"-shaped hooks, supported by bars. H.T.

PATENT

Enamel. FIRMITANA METALLKERAMIK G.M.B.H. Ger. 608,807, Feb. 1, 1935; *Chem. Abs.*, **29**, 5244 (1935). A method of firing enamel without the aid of a muffle furnace, by heating the reverse side of the enamelware by a gas or electric source of heat, is described.

Glass

Alternating and direct current surface conductivity measurements in Pyrex slits. F. URBAN, S. FELDMAN, AND H. L. WHITE. *Jour. Phys. Chem.*, **39** [5] 605–609 (1935).—The apparent d.c. specific surface conductivity is lower than a.c. conductivity, due to membrane potentials. The apparent d.c. specific surface conductivity of fractured glass is the same as that of smooth capillaries. C.J.P.

Automatic production important factor in glass container plant. E. M. DEREMER. *Ind. Gas*, **13** [10] 14 (1935).—A new plant of modern design is described. The designer satisfied the following requirements: (1) handling from a central point by a single man; (2) all sand handled wet; (3) the most efficient furnaces obtainable for handling type of fuel and capacity (the new plant has three times the capacity of the old plant); (4) use of two grades of sand and three grades of cullet; and (5) automatic glassmelting tank, adjusted to give a feed volume corresponding to any size of glassware from 1 oz. to the largest container made. J.M.K.

Changes in the coloring of glasses. L. SPRINGER. *Glashütte*, **65** [25] 375–76 (1935); abstracted in *Verre & Silicates Ind.*, **6** [14] 263 (1935).—In perfectly white glasses in a solid state, chemical reactions can be produced which cause the color of iron, the rose of selenium, or the gray of nickel oxide to reappear. During refining, the effect of gas, oxidizing or reducing, is not important according to Höfler. The color of iron is concealed by that of the selenide of iron (reddish-brown). Changes in coloring during refining are possible when the iron-oxide content exceeds 0.02% which is almost always the case. In the presence of arsenic, selenium glasses become rose or brown on refiring. Cerium, selenium, and arsenic glasses show varying changes in tint. Arsenic is not a stabilizer. Very alkaline glasses are the least stable. Nickel has sometimes had a very bad effect. S. proposes the use of chemical decolorants (saltpeter and arsenic); physical decolorants (manganese, nickel, selenium) only serve to obliterate the rest of the coloring. The Auer Ges. proposes decoloration with cerium with a little manganese. The glasses come from the furnace with a slight brown tint which disappears in the light. S. points out the effect of ultra-violet and X-rays. M.V.C.

Chemicals that accelerate melting. ANON. *Glass Ind.*, **16** [9] 273 (1935).—The effect of the addition of borax, ammonium sulfate, ammonium chloride or ammonium nitrate, barium salts, sodium chloride, a mixture of potash and soda, or hydrous calcium sulfate in accelerating the melting of glass batches is discussed on the basis of work of various investigators. E.J.V.

Concerning tuckstones. JOSEPH EARLY. *Glass Ind.*, **16** [9] 265–69 (1935).—To avoid difficulties caused by the difference in the expansion rate of various materials used, the silica side walls are constructed so that they are supported independently of the flux blocks. The tuckstone must also protect the tops of the flux blocks from exposure to the batch fumes and the high flame temperature, both of which cause rapid erosion. The requirements of the tuckstone are support, flexibility, simplicity, protection, and accessibility. Various types of tuckstones and tuckstone connections are described, illustrated, and discussed. E.J.V.

Course in glassmaking. ANON. *Verre & Silicates Ind.*, **6** [13] 242–43 (1935).—In the manufacture of colored glasses, immediate coloration, coloration by saturation, and coloration by cementation are discussed briefly and notes on gold, copper, selenium, and tellurium reds are given. For previous abstract see *Ceram. Abs.*, **14** [8] 184 (1935). M.V.C.

Critical examination of the problems of re-oxidation of glasses permeable to ultra-violet. JOSEPH HOFFMANN. *Glastech. Ber.*, **12**, 53–56 (1934).—Changes in the valence of iron atoms as a function of the action of heat and light and the effect of light compared to the action of heat which is more easily controlled are discussed. The following subjects are studied: (1) the diminishing of the permeability to ultra-violet of glasses, (2) valence of Fe atoms, (3) valence as a function of the wave-length, (4) β,γ, and Röntgen waves, and (5) cations and anions of Fe atoms. M.V.C.

Crystallization of pigments in selenium ruby. A. N. DAUVALTER. *Keram. i Steklo*, **11** [5] 30–34 (1935).—(1) By keeping red and orange selenium glasses at 1050°C for a longer time, intensively red crystals of 3 types, mainly the hexagonal type which is the separated compound producing the red coloring of selenium rubies (probably CdSe), are obtained. (2) Yellow crystals (CdS) of the same type are obtained in yellow cadmium sulfide glasses with little selenium at temperatures below 1050°. (3) The theory of Rooksby that the coloring of selenium rubies is due to the separation of CdSe and CdS as ultra-microscopic crystals, whose coloring and quantitative proportion produce the glass coloring independently of the degree of dispersion of the crystals separated, was confirmed. (4) Most of the crystals that separated belong to the hexagonal system. (5) The red and yellow colorizers (CdSe and CdS) separate, not as mixed crystals (solid solution), but separately as pure red and pure yellow crystals. (6) The glass is colored by sulfide and cadmium only after their crystallization. Those remaining dissolved, *i.e.*, molecularly dispersed, do not color the glass. (7) Both pigments separate in various moments of crystallization and temperature intervals and in different proportions unequal to their relative content in glass. (8) Quantitative relationships between the crystallizing pigments depend on their concentration in the glass and temperature. (9) The crystallization and growth of colloidal particles of free selenium is excluded in selenium ruby. (10) It is quite possible that other pigments, such as $CdSSe_n$, are formed in glass in addition to CdSe and CdS. (11) The differences (from the chemical viewpoint) in types of glass, that colored by Se and CdS (ruby) and that colored by Se only (rosalin), are pointed out. (12) The compound $CdS+nS=CdSSe_n$, which later disintegrates into $CdS+nSe$ or $CdSe+S+(n-1)Se$, depending on the conditions of melting, is formed first when melting selenium ruby. M.V.C.

Determination of mean specific heats at high temperatures of some commercial glasses. C. W. PARMELEE AND A. E. BADGER. *Univ. of Ill. Bull.*, **32** [271] 3–22 (1934).—The specific heat of nine different glass samples was determined in the interval between 40 and 1050°C. The calorimeter and method used are described in detail. A soda-lime bottle glass had 0.298 cal./g./°C; another of

the same composition used for electric lamp bulbs had 0.290; a glass for milk bottles 0.293, a plate glass 0.289, a lead glass 0.224, a borosilicate glass 0.287, and an opal glass 0.269. The exact composition of the various glasses is given. M.H.

Development of recuperators for tank furnaces. TH. TEISEN. *Atti I° congr. internat. vetro e ceram.* [Milan], pp. 612–37 (1933); abstracted in *Verre & Silicates Ind.*, **6** [9] 130 (1935).—European types of recuperators for tank furnaces have been adopted in the U.S. although the Morton type is an innovation. This recuperator of the tubular type makes the air as well as the smoke circulate vertically. Although cleaning is difficult, results are satisfactory and this type has also been adopted in Europe. The burners can be arranged for transverse flames or horseshoe. This latter simple system is suitable for recuperators for tanks, but it is difficult to keep the length of the flame and the temperature of the work tank constant. Different corrections are used: outlet burners near the bridge, latticed walls, independent firing for the work tank, Amsler-Morton double arch. T. devised the duplex type in which the inlet burners are in the gable and the outlet burners, at the end of the melting tank, are connected with the work tank. By means of regulators, all or part of the hot gas can be forced to pass into the work tank and can be regulated for the mechanical work. T. shows that the recuperators (with hexagonal tubes) can be placed below or above the tank and that oil burners should not consume more than 10% primary air. M.V.C.

Effect of CO_2 in the gas medium on the melting of glass. M. A. BESBORODOV, A. A. SOKOLOVA, AND G. A. SHINKE. *Keram. i Steklo*, **11** [5] 26–30 (1935).—(1) Soda and sulfate batches were melted at 900, 1000, 1100, 1200, and 1300°C in air and in CO_2. (2) A transparent glass with tiny bubbles was obtained at 1200° without traces of unmelted batch. At 1300°, colorless glass without bubbles was obtained when melting in air. It had a bluish-greenish tint when melted in CO_2. (3) Pure transparent glass with tiny bubbles was obtained at 1300° from sulfate batches. The glass is not homogeneous at 1200°, and the mass has a glass-like appearance but is not transparent. CO_2 has no marked effect on the amount of bubbles in the glass. (4) A chemical study of soda melts as to the CO_2 remaining in them showed that (*a*) the absolute amount of CO_2 present in all melts is quite small (not higher than 0.13%); (*b*) the amount of CO_2 gradually decreases with increasing temperature but does not fall to less than 0.05%; and (*c*) melts obtained in CO_2 always contain more of it; this difference, however, is so small (0.02%) that it has no practical effect. (5) The chemical analysis of sulfate melts showed that (*a*) the absolute amounts of CO_2 are very small; (*b*) the CO_2 content decreases with increasing temperature; and (*c*) melts obtained in CO_2 always contain more of it than those melted in air. (6) Chemical study of sulfate melts as to their SO_3 content showed that (*a*) the curve of the SO_3 content has a maximum at 1100° in all melts whether they were melted in air or CO_2; the SO_3 content decreases with increasing temperature; (*b*) melts produced in CO_2 have a higher SO_3 content than those melted in air; and (*c*) the maximum on the SO_3 curve at 1100° is due to an interchangeable disintegration of the components of the batch and variable solubility of silicates, gases, and batch components at various temperatures. (7) Experiments showed that CO_2 has no marked effect on the degree of purity of the glass. M.V.C.

Effect of small quantities of components on the quality of present-day glasses. ZSCHACKE. *Glashütte*, **65** [22] 335–36 (1935); abstracted in *Verre & Silicates Ind.*, **6** [13] 245 (1935).—The influence of small quantities of secondary constituents is discussed. With the exception of arsenic, laboratory tests on small quantities of materials can not duplicate the processes occurring in industrial furnaces because of the difference in the time interval and quantities involved. Experience in plants must decide the value of secondary components. Borax is one of the most useful components, having been introduced with the development of automatic machines which necessitated a simplification of the mix and a more alkaline glass. In order to better the chemical resistance, a fourth ingredient had to be added: Al_2O_3, BaO, B_2O_3, MgO, or ZnO. Borax was found to be best. For 100 parts of sand, 4 to 5 parts of borax give 1 part of B_2O_3 in the glass. Fusion and refining are facilitated and the furnace output is augmented, sometimes 40%. Chemical and thermal resistance, elasticity, and life period are improved and defects reduced. M.V.C.

Electrical conductivity of boron trioxide-sodium borate glasses. M. E. SPAGHT AND J. D. CLARK. *Jour. Phys. Chem.*, **38** [6] 833–38 (1934).—The electrical conductivities of boron trioxide, sodium borate, and several boron trioxide-sodium borate systems are measured over a 240°C interval using an improved Wheatstone bridge method. Pure B_2O_3 and pure $Na_2B_4O_7$ show smooth conductivity curves over the whole temperature range. Mixed glasses give sharp breaks in the transition region. Addition of small percentages of $Na_2B_4O_7$ to B_2O_3 causes the conductivity to decrease, but further addition causes a steady increase. C.J.P.

Engineering problems encountered in making a 200-inch telescope disk. G. V. MCCAULEY. *Bull. Amer. Ceram. Soc.*, **14** [9] 300–22 (1935).

Fabrication of containers. G. B. LANGER. *Glass Ind.*, **16** [9] 281 (1935).—L., a practical mold-maker, offers some observations to production men. Regularity in feeding batch material to the tank and regular furnace reversal periods help eliminate temperature fluctuations in the feeder. Care to attain the proper glass temperature for working and to maintain this at a constant level will enable the feeder to function properly. The formation of a cool skin, which causes an uneven distribution of glass or a "settle wave," will be avoided if the gob is charged as quickly as possible from the feeder into the mold. Proper mold design will also eliminate much "off-ware." E.J.V.

Filter glasses and their relation to optics. MARIO CONTI. *Atti I° congr. internat. vetro e ceram.* [Milan], pp. 424–31 (1933); abstracted in *Sprechsaal*, **66** [52] 886 (1933); *Glashütte*, **63** [49] 835 (1933).—Researches on various mono- and pluri-chromatic filter glasses for photographic purposes, optical instruments, and pyrometry are dealt with. The analytical and investigating methods and the important properties of these glasses and their spectra are discussed. M.V.C.

Fusing opal in a tank: tunnel kiln. D. R. *Verre & Silicates Ind.*, **6** [12] 226 (1935).—The miniature tunnel kilns used instead of pot furnaces in U.S. for the automatic production of small quantities of glass of different chemical composition and color are described and their advantages given. M.V.C.

Glass as a German industrial material for chemical apparatus. Von Stoessser. Presented at the Dechema, 1935; abstracted in *Glashütte*, **65** [30] 458 (1935).—The physical and chemical properties of special glasses used in chemical apparatus are compared with the properties of other materials used in them. Examples of the use of glass in apparatus are described. M.V.C.

Glass silk for heat insulation. Anon. *Eng. Boiler House Rev.*, **48** [3] 182–84 (1934).—Glass silk can be employed up to 1100°F. A test conducted at 600°F showed a loss of 225 B.t.u./sq. ft. of glass silk one inch thick. The heat loss through the same area of plastic magnesia of the same thickness was 300 B.t.u. H.K.

Hardened glass "Vit-Rex." A. Quentin. *Atti I° congr. internat. vetro e ceram.* [Milan], pp. 571–76 (1933); abstracted in *Sprechsaal*, **66** [52] 887 (1933); *Glashütte*, **63** [49] 836 (1933).—This type of hardened glass was developed during the World War for the Italian Navy. In 1926, the "Società Quentin" was the first to chill both sides of the glass plate with blown air. This glass is not dangerous when it breaks because it crumbles into round particles. On sudden cooling, it hardens like steel except that steel undergoes a physicochemical change of its structure, while glass changes its molecular arrangement and in this way reaches a high mechanical strength. M.V.C.

Heat-stable glasses. H. W. Howes. *Atti I° congr. internat. vetro e ceram.* [Milan], 1933; abstracted in *Glashütte*, **63** [49] 834 (1933).—A review of the properties of glasses stable to heat and a short description of new developments in this field are given. M.V.C.

High-frequency conductance of Pyrex-brand glass in the presence of vapors. W. M. Roberds. *Physics*, **6** [7] 227–33 (1935).—The electrical conductance of Pyrex-brand glass 774 was measured at frequencies between 40 kc. and 1000 kc. in the presence of ethyl-alcohol vapor and water-vapor. Data were taken at 50, 65, 79, and 107°C. The relations between conductance, degree of saturation, and frequency were found to be of the same form at all temperatures. There is a distinct discontinuity in the curves of conductance *vs.* frequency at about 500 kc. Vapor pressures of alcohol up to 85% of saturation cause no change in the conductance of the test piece. Above this degree of saturation, however, the conductance increases rapidly with pressure, becoming very high if condensation occurs. Conductance decreased with increasing current unless the test element was aged in the vapor several hours. Surface conductivities for both alcohol and water-vapor are computed. Those for water-vapor agree, well within the limits of error, with the results found by Yager and Morgan. An unexplained resonance effect occurred when high currents were used to measure the conductance while the test element was in the presence of small amounts of either alcohol or water-vapor. The effect shows the double-resonance peak and many of the other characteristics of close coupling between oscillating circuits. The effect, however, in some way is due to the energy absorbed in the test element in the presence of a minute amount of water or alcohol since either an increase or decrease of pressure will cause the disappearance of the phenomenon. It was impossible to produce the effect by the substitution of any combination of capacity and artificial leak.

Iwaki's colored glasses as filters. T. Futagami. *Bull. Inst. Phys. Chem. Research* [Tokyo], **13** [11] 1328–39 (1934) in Japanese; abstracted in appendix to *Sci. Papers Inst. Phys. Chem. Research* [Tokyo], **25**, 530–34 (1934); *Physik. Ber.*, **16** [6] 517 (1935).—The spectral permeability curves of forty-five colored glass filters were determined, and fields of application are discussed. M.H.

Manufacture of glass tubes. J. Cardot. *Verre & Silicates Ind.*, **6** [12] 217–22 (1935).—The manufacture of glass tubes has progressed since the beginning of this century to the same extent as other branches of the glass industry. The different processes used today are described, *e.g.*, manufacture by hand, mechanical method, the Fabre machine, Danner machines, Vello machine, overflow machines, and Wood machines. M.V.C.

Melting glass in electric furnaces. G. Zaniol. *Atti I° congr. internat. vetro e ceram.* [Milan], 1933; abstracted in *Glashütte*, **63** [47] 793 (1933).—Z. describes the installation and operation of the first electric-resistance furnace for melting glass used in Europe and discusses its use for melting chemical apparatus glass and optical glass. M.V.C.

Method for the preparation of copper-glass mirror. Jiro Noto and Jyunpei Uno. *Jour. Electrochem. Assn. [Japan]*, **2**, 375–79 (1934); *Chem. Abs.*, **29**, 1597 (1935).—Reduction of Fehling solution by 3.5 to 7% Ch_2O in the presence of a very small amount of Ag salt has been recommended. The compound of Fehling solution may be somewhat widely divergent, that of anhydrous $CuSO_4$ 2 g., crystalline Rochelle salt 4 g., KOH 4 g., and distilled water 100 cc. being the best. $CuSO_4/AgNO_3 < 10$ is preferable.

Methods of investigating the constitution of glass. W. E. S. Turner and E. Preston. *Atti I° congr. internat. vetro e ceram.* [Milan], pp. 551–65 (1933); abstracted in *Sprechsaal*, **66** [52] 887 (1933); *Glashütte*, **63** [47] 794 (1933).—Those methods which separate glass into definite chemical components and those which attempt to show the nature and properties of the state of glass are included. The first method is based on the equilibrium diagram, the second is concerned with the question of whether or not glass is a solid body or an undercooled liquid. The various transformation points of glass on heating are discussed in detail. From the studies of density, specific volume, X-ray diagrams, electric resistance, and steam pressure, it may be concluded that some definite components exist in the glassy state. The presence of $Na_2O{\cdot}2SiO_2$ and $Na_2O{\cdot}SiO_2$ was determined up to high temperatures. M.V.C.

Mineral wool made of glass. D. C. Simpson. *Refrigerating Eng.*, **29**, 195–96 (1935); *Chem. Abs.*, **29**, 5200 (1935).—The use of glass wool as an insulant is discussed.

Performance history of glass tanks. J. W. Romig. *Glass Ind.*, **16** [9] 271–72 (1935).—To keep proper histories on which to base changes in glass tank design or operating schedules, a complete but easily summarized set of records

should be kept. R. sets up a table of the most important items entering into performance and a second table of items of particular interest that are found from information in the first table. Careful check of data in these tables will show reasons for changes, if any are to be made. E.J.V.

Preparing glass free from iron. I. I. KITAIGORODSKIĬ AND L. S. LANDE. *Compt. rend. acad. sci., U.R.S.S.*, **3** [4] 267–70 (1934).—In some cases iron oxides can be almost completely removed from sand by the addition of chlorides in the presence of oxidants, after a preliminary heating of the sand to 575 to 600° or after finely grinding it (or both simultaneously). A method of cleaning appropriate for all cases can not be proposed because it varies with the peculiarities of the sand. P.B. & E.S.

Problems of the glass-bottle industry. W. A. MOORSHEAD. *Trans. Inst. Chem. Engrs.* [London], 13 pp. (Jan. 9, 1935); *Chem. Abs.*, **29**, 1597 (1935).

Quartz ware, a German industrial material for chemical apparatus. VON BEAULIEU-MARCONNAY AND TH. FRANTZ. Presented at the Dechema, 1935; abstracted in *Glashütte*, **65** [30] 458 (1935).—The manufacture of quartz ware from German raw materials is discussed. It is based on the melting of sand in an electric-resistance furnace. The properties of quartz ware are discussed in detail. M.V.C.

Röntgen spectrographs with bent crystal. A. MAKHALOV. *Zhur. Tekh. Fiz.*, **4** [5] 895–909 (1934).—The subject is surveyed. S.I.P.

Submarine throat in a glass tank. JAMES ARRANDALE. *Ceram. Ind.*, **25** [3] 129–30 (1935).—As the greatest amount of erosion on the throat of a glass tank is upward, the drop throat was developed to increase the life of the throat. Some manufacturers have discontinued its use because of its inability to produce glass free from seed; some claim that it runs too cold so that the nature of the glass passing through it is changed; while others contend that it tends to increase the quantity of surface glass entering the working chamber from the melter. In all bridge-type furnaces, there is always a hot spot directly in front of the throat on the working side. The straight-throat type tank produces a better mixed glass in the working chamber and a more uniform temperature is maintained. Illustrated. E.J.V.

Unit furnace for window-glass production. THOMAS B. HART. *Ceram. Ind.*, **25** [3] 136 (1935).—Unit furnaces have made possible the coördination of output with orders. A unit window-glass tank furnace can be designed in up- and down-draft, regenerative, and recuperative types. A drawing depicting the features of such a furnace is shown and a description is presented. E.J.V.

Selenium for decolorizing glass. R. D. AND L. F. Translated in *Glass Ind.*, **16** [9] 283–87 (1935); see *Ceram. Abs.*, **14** [8] 187 (1935). E.J.V.

Variation of the refractive index of non-annealed glass as function of time. NIUTA KLEIN. *Compt. rend.*, **201** [5] 41 (1935).—From measurements of the refractive index at the same place of a glass which was not subjected to any heat treatment, it was concluded that the index varies with time in spite of any thermal treatment and that this variation is maximum at places where the original index was the smallest and *vice versa*. The reason for such change is seen in the transformation of the β-modification of the glass into the α-modification which had not had the time to take place due to too rapid cooling. This theory seems to find corroboration by the fact that the curve representing the change has an exponential characteristic which points to a molecular phenomenon. M.H.

Viscosity of fused rocks. M. P. VOLAROVICH. *Compt. rend. acad. sci. U.R.S.S.*, **1**, 561–64 (1934); abstracted in *Chem. Zentr.*, **i**, 3180 (1935).—The viscosity of fused basalt, teschenite, andesite, diabase, and ordinary bottle glass were measured between 1100 and 1400°. Andesite has the highest viscosity. Andesite and teschenite easily change into the glassy state. M.V.C.

BOOKS

Cold Treatment of Optical Glass. A. N. BARDIN, V. A. SMIRNOV, AND B. B. KHOMENKO. Edited by L. G. Titov. Pub. House of the All-Union Assn. of the Optical and Mechanical Ind., Leningrad, 1934. 150 pp. Price 9R. 75k. This book is devoted to cutting, roughing, grinding, milling, and drilling of optical glass. S.I.PERKAL

Directory for the British Glass Industry. GEORGE S. DUNCAN. 3d revised ed. Society of Glass Technology, Sheffield, England, 1934. 416 pp. Price 4s. This directory is divided into 10 sections as follows: (*A*) alphabetical list (with particulars) of manufacturers of lamp-worked and scientific glassware and optical apparatus, glass manipulators, craftsmen in stained glass, etc.; (*B*) classified lists (names only) of firms entered in section (*A*); (*C*) glass merchants and wholesale dealers; (*D*) alphabetical list (with particulars) of firms supplying this industry with machinery, oils, chemicals, refractories, and grinding, polishing, and packing materials; (*E*) classified lists (names only) of firms in section (*D*); (*F*) industrial associations; (*G*) trade unions and their officials; (*H*) city companies; (*I*) educational institutions and scientific societies; and (*J*) publications, (*a*) recent books, (*b*) current periodicals (in this list, two publications of the American Ceramic Society have not been mentioned).

This directory is a complete, accurate, interesting, well-arranged, and informational handbook on English glass and kindred industries. All the items are comprehensively described and alphabetically arranged. Authoritative information on the British glass industry is given. SELICK I. PERKAL

Experimental Researches and Reports. Vol. 16. ANON. Department of Glass Technology, Sheffield, 1933. 180 pp. Price 7s. 6d. This publication consists of papers published by members of the Department of Glass Technology, The University, Sheffield, England. The volume for 1933 contains 16 papers (researches, reports, etc.) taken mainly from *The Journal of the Society of Glass Technology* and from the Department's monthly publication, *The Glass Review*. SELICK I. PERKAL

Mechanical Manufacture of Sheet Glass. S. I. KOROLEV. Edited by A. A. Trusov. State Pub. House of Light Ind., Moscow and Leningrad, 1935. 83 pp. Price 1R 10k. S. I. PERKAL

Technical and economic features in the utilization of blast-furnace slag in glass manufacture. CLEBURNE A. BASORE AND L. HOWARD HULL. *Alabama Polytech.*

Inst., Eng. Expt. Sta. Bull., No. 6, 52 pp. (1934); *Chem. Abs.*, **29**, 565–66 (1935).—Experiments to utilize blast-furnace slag in glass manufacture have been successful for four types of glass prepared under optimum conditions: (1) transparent Al glass, (2) black opaque glass, (3) laboratory or "chemical" glass, and (4) opal glass; (1) and (2) have been made on a semicommercial scale. The savings in cost of raw materials was 35 to 75%, and the glasses showed superior thermal endurance, chemical stability, tensile strength, impact resistance, and resistance to shattering when broken. Drawings and specifications with an estimate of equipment needs are included. See also "Blast-furnace—" *Ceram. Abs.*, **14** [6] 135 (1935).

Work of the "Pav" Machine. Ya. A. Shkolnikov. State Pub. House of Light Ind., Moscow and Leningrad, 1935. 124 pp. Price 1R 30k. This is a textbook of the technical minimum for workers of the glass industry. It is devoted to a description of work on the Miller automatic press (Pav) system for hollow-ware manufacture.

S. I. Perkal

PATENTS

Apparatus for continuously drawing glass tubes. Leopoldo Sanchez-Vello. Ger. 608,835, Feb. 1, 1935; *Chem. Abs.*, **29**, 5243 (1935).

Art of laminating glass. A. W. Hornig. U. S. 2,013,213, Sept. 3, 1935 (April 26, 1930).

Borosilicate glass composition. W. C. Taylor (Corning Glass Works). U. S. 2,012,552, Aug. 27, 1935 (May 24, 1932). A batch for making brown glass comprises, in addition to the ordinary glass composition, 0.5 to 3.0% of ammonium sulfate and 0.5 to 5.0% of organic matter.

Brown glass batch. Kitsuzo Fuwa and Fujio Suzuki (General Electric Co.) U. S. 2,014,230, Sept. 10, 1935 (June 8, 1932). A borosilicate glass has a thermal coefficient of expansion of about 0.000005 and consists essentially of silica 72, magnesia 12, boric oxide 8, sodium oxide 6, and potassium oxide 2%.

Glass. Walter Becker. Ger. 609,944, Feb. 28, 1935; *Chem. Abs.*, **29**, 5242 (1935). Glass containing heavy metals, metalloids, or their compounds is ornamented or decorated by treating the surface with a reducing flame to cause deposition of the metal. The method is specially effective for glasses containing Cu, Pb, As, Sb, Te, Se, or Au. An O-H, O-C_2H_2 flame or an electric arc may be used.

Glassforming machines. A. W. Parfitt (Europäischer Verband der Flaschenfabriken Ges.). Brit. 433,836, Sept. 4, 1935 (Nov. 8, 1934).

Glass holding and breaking device. C. M. McCarthy. U. S. 2,013,216, Sept. 3, 1935 (Oct. 6, 1933).

Glassworking machine. B. T. Headley and D. I. Du Bois (Hartford-Empire Co.). U. S. 2,013,463, Sept. 3, 1935 (May 3, 1928).

Heat insulation. C. G. Munters. U. S. 2,012,617, Aug. 27, 1935 (Feb. 26, 1932). A method of producing heat insulation consists in mixing a substance such as zinc, cadmium, etc., preferably in the form of powder, into a mass, consisting, *e.g.*, of glass, heating the mixture to the melting temperature of the mass, lowering the pressure to permit the substance to evaporate thereby forming numerous cells or pores in the mixture, and cooling the mass under vacuum. A glass foam has condensed metal within its cells.

Leer with roller beds. F. B. Waldron (Pilkington Brothers, Ltd.). U. S. 2,014,302, Sept. 10, 1935 (Dec. 8, 1933).

Manufacture of cellular glass. Soc. anon. des manufactures des glaces et produits chimiques de St. Gobain, Chauny, et Cirey. Brit. 433,423, Aug. 28, 1935 (Jan. 27, 1934).

Manufacture of glass sheets. Edlo Donnini (American Window Glass Co.). U. S. 2,013,459, Sept. 3, 1935 (June 30, 1933).

Manufacture of hardened or tempered glass plates. Assurex Le Roi des Verres de Securite Magnien, Monnier, & Cie. Brit. 433,748, Sept. 4, 1935 (June 8, 1934).

Method and apparatus for supplying molten glass. Thomas Waugh, Jr. (Hartford-Empire Co.). U. S. 2,014,075, Sept. 10, 1935 (April 19, 1933).

Method of feeding glass. E. C. Stewart (Tygart Valley Glass Co.). U. S. 2,013,451, Sept. 3, 1935 (Feb. 2, 1933).

Method of making multiple bottles. C. B. Garwood (Carr-Lowrey Glass Co.). U. S. 2,013,382, Sept. 3, 1935 (Nov. 4, 1933).

Method of manufacturing bottles, etc. L. G. Bates (Hartford-Empire Co.). U. S. 2,012,583, Aug. 27, 1935 (June 6, 1934).

Method of manufacturing laminated glass. F. L. Bishop (American Window Glass Co.). U. S. 2,014,124, Sept. 10, 1935 (Aug. 15, 1931).

Process for silvering glass or similar transparent or translucent materials. Duro-Ray, Ltd., and A. M. Barnes. Brit. 432,587, Aug. 14, 1935 (Feb. 8, 1934).

Purifying sand, etc. Rockware Glass Syndicate, Ltd., and Frederick W. Adams. Fr. 778,100, March 8, 1935; *Chem. Abs.*, **29**, 4539 (1935). See Brit. 423,053, Feb. 6, 1935, *Ceram. Abs.*, **14** [5] 114 (1935).

Quartz glass. Chû Onoda, Rokutarô Kawamura, Minoru Kiyono, and Ryûichi Sano. Japan. 110,082, March 26, 1935; *Chem. Abs.*, **29**, 5243 (1935). Crushed materials (such as silica, quartz) are boiled with a strong mineral acid to remove impurities, elutriated, and heated at 400 to 1000° to remove bubbles, etc., and then melted to glass at 1500 to 2000°.

Sheets of glass. Forges et ateliers de constructions électriques de Jeumont. Fr. 778,338, March 14, 1935; *Chem. Abs.*, **29**, 4538 (1935).—The sheets are cooled until the glass solidifies, reheated for a short time to render the exterior layers plastic, and then cooled, quickly or not, to the final temperature for polishing.

Structural Clay Products

Brick house for $2295. Metropolitan Paving Brick Co. *Brick Clay Rec.*, **87** [2] 47 (1935).—A description of a veneer brick house of special design, with four rooms and bath included in 600 cu. ft. of space, is given. Construction details are also given. Illustrated. E.J.V.

Colored facing brick. I. I. Slobodyanik and I. N.

ZAIKA. *Stroitel. Material.*, No. 3, pp. 50–51 (1935).—Red, lemon-yellow, and silver-black brick were obtained by an appropriate selection of clays and firing schedules without any addition of colorants. P.B. & E.S.

Coloring and efflorescences in brick. HIELSCHER. *Tonind.-Ztg.*, **59** [46] 555–56 (1935).—The oxidizing and reducing firing of brick in chamber and zigzag furnaces and its effect on coloring and efflorescences is discussed. M.V.C.

De-airing of floor tile. DOUGLAS F. STEVENS AND ROBERT P. STEVENS. *Bull. Amer. Ceram. Soc.*, **14** [9] 291–93 (1935).

Fine sand for the production of lime-sand brick. E. D. PEVSNER. *Stroitel. Material.*, No. 3, pp. 44–49 (1935).—Clean fine sand can be used, and an increased proportion of lime is required, which can be decreased by using a determined amount of coarse sand containing 50% or more of quartz grains. P.B & E.S.

Part of the brick manufacturer in the better-housing program. W. D. RICHARDSON. *Bull. Amer. Ceram. Soc.*, **14** [9] 293–96 (1935). **Addendum.** *Ibid.*, **14** [10] 336–37 (1935). **Discussion.** FREDERICK HEATH, JR. *Ibid.*, **14** [9] 296–98 (1935).

Reinforced-concrete columns. F. E. RICHART AND R. L. BROWN. *Univ. of Ill. Bull.*, **31** [267] 3–91 (1934).—The strength of reinforced-concrete columns, their behavior under various conditions of loading, and proper rules for design were investigated; test methods are described. A number of design formulas is developed and factors affecting their choice in a given case are discussed. M.H.

Resistance of clays to gas penetration. FREDERICK G. JACKSON. *Bull. Amer. Ceram. Soc.*, **14** [9] 298–99 (1935).

Soft-mud brick on a stiff-mud yard. H. L. LONGENECKER. *Brick Clay Rec.*, **87** [2] 50 (1935).—Since imitation soft-mud brick made by rubbing sand into the stiff-mud column to make a sand-finish brick did not fill an order for handmade brick, a soft-mud machine was used with mud from the auger machine. Drying brick on wooden pallets in a waste-heat tunnel drier resulted in the pallets igniting. Impregnating the wooden pallets in 50% sodium-silicate solution made them sufficiently fire-resistant to prevent further fires. Sand-finish brick can be produced in a variety of colors not found in stiff-mud face brick. E.J.V.

Victory for stoneware pipe. ANON. *Clay Prod. Jour. Australia* **2**, 21 (July, 1935).—A committee of New South Wales Government engineers made an investigation extending over several months on the life of pipe of various materials in actual service. The unanimous findings represent a testimony to stoneware. H.H.S.

BOOK

Building Materials. Edited by B. P. GORBUSHIN. All-Union Sci.-Research and Experimental Inst. Housing Construction Industrialization. State Sci.-Tech. Pub. House of Bldg. Ind. and Shipbuilding, Moscow and Leningrad, 1934. 144 pp. Price 2R 25k. To industrialize housing construction, this Institute has undertaken work on (1) new constructions, (2) new building materials, and (3) new methods of work. As the cost of building materials in a house is about one-half of its total cost, the rôle of these materials in the general problem of housing construction industrialization is important.

The book represents a symposium of papers, the results of the work of the Institute in its first year, devoted to new building materials as follows: (1) waterproof and hydraulic unfired clay mortars, (2) fibrolite on the basis of unfired clay mortars, (3) new kinds of fibrolite developed by the Institute, (4) organic pressed building materials, (5) utilization of clays and fired rocks, and (6) results of work of the central experimental station of the Institute for 1931.

Lists of references on the subjects and of 57 publications of the Institute are appended. The book contains reliable, practical data. S. I. PERKAL

PATENTS

Building construction. M. W. THOMPSON. U. S. 2,013,367, Sept. 3, 1935 (April 29, 1933). A vertical building wall structure is formed of a plurality of superimposed, directly contacting, preformed blocks, the blocks of each row being staggered with relation to the blocks of the adjacent rows, each block being substantially rectangular in horizontal section and provided with a pair of inclosed openings therethrough, the blocks of alternate rows being arranged in vertically alined series, and the openings through the blocks of the respective rows being alined to form a plurality of vertical passages, load-carrying cementitious columns formed in certain of the vertical passages with their upper ends terminating substantially in the plane of the upper faces of the uppermost row of blocks, certain of the columns being spaced apart a distance greater than the width of certain of the vertical series of blocks whereby the blocks in the latter series are maintained in position solely by engagement with adjacent blocks, a beam extending over and supported by the upper ends of the columns, and a superstructure supported by the beam.

Building material. C. C. WHITTIER (Leonora A. Whittier). U. S. 2,012,798, Aug. 27, 1935 (Feb. 23, 1931). A substantially hard and nonbloated, heat-treated, ceramic block has a body or cellular structure provided with a plurality of closed cavities formed by the combustion of hydrocarbons distributed substantially uniformly throughout its volume, and has throughout the ceramic material comminuted granular heat-resistant strengthening elements intimately mixed therewith, the block body having roughened surfaces formed by open partial cavities therein.

Clay and similar pipes, conduits, and etc. W. M. W. SUTTON. Brit. 432,579, Aug. 14, 1935 (Feb. 1, 1934).

Insulating building and sound-absorbing material. W. T. DEAN (Calicel Products, Inc.). U. S. 2,014,065, Sept. 10, 1935 (Jan. 10, 1929). An insulating material consists of small cellular masses of rock sponge mixed with plastic material to form blocks and fired.

Sound-insulating wall, paving, etc. F. A. GRASSI. Brit. 429,803, June 19, 1935 (April 4, 1933).

Refractories

Action of alkalis on refractory materials. II. F. H. Clews, A. Green, and A. T. Green. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 41–55 (1934).—A report is given of the action of potassium-chloride vapor on refractories at 1000°C. In the absence of moisture, the silica refractories notably resist attack to a greater extent than fire clay, which confirms the finding of other workers. The results form a starting point for the projected investigation of the effect of temperature and moisture on these reactions. H.E.S.

Agalmatolite as a grog for refractory materials in the glass industry. Bruno Hofmann. *Sklarske Rozhledy*, **11**, 140–43 (1934); abstracted in *Chem. Zentr.*, **i**, 2063 (1935).—The Czechoslovak clay-rock, agalmatolite, shows considerable formation of mullite when heated. Its composition (calcined) is 64.41 SiO_2, 33.45 Al_2O_3, 0.73 TiO_2, 0.75 Fe_2O_3, 0.35% MgO; traces of $CaO \cdot SiO_2$ are present in a combined state. M.V.C.

Alumina production at the Volkhov aluminum plant. M. M. Laboda. *Legkie Metallui*, **4**, 27–31 (Jan., 1935); *Met. Abs.* (in *Metal & Alloys*), **6** [7] 273 (1935).—Formerly the charge, consisting of 44 bauxite, 18 $CaCO_3$, and 38% Na_2CO_3, was calcined and Al_2O_3 extracted with H_2O at 25°. Due to poor results the charge was changed to 49 bauxite, 28 $CaCO_3$, and 23% Na_2CO_3, and the resulting calcine was leached with Na_2CO_3 solution at 70°. The output of this plant in 1934 increased 90% over 1933, reaching 15,000 T. Al_2O_3; the cost decreased from 1317 to 903R. per ton, and the productivity of labor more than doubled. The analysis of the Al_2O_3 was 0.24 SiO_2, 0.04 Fe_2O_3, 0.08 CaO, and 0.40% Na_2O.

Brickmason and the open-hearth furnace. IV. Henry D. Tyson. *Blast Fur. Steel Plant*, **23** [9] 616–18 (1335).—The slag pocket, located between the checker chamber and the furnace proper, consists of an outer permanent section of heavy red brick walls, with a lining of silica brick generally covered with clay or loam to protect them against hot slag erosion. Considerable care must be exercised in putting in expansion joints. For Part III see *Ceram. Abs.*, **14** [10] 248 (1935). E.J.V.

Changes in the chemical composition of refractories for blast-furnace use during their service. R. N. Golovatniĭ and I. A. Smolyanitzkiĭ. *Ogneuporui*, **2** [12] 21–25 (1934).—Samples of refractories from different parts of a blast furnace that had been shut down for repair were investigated. The sample taken 2100 mm. from the throat showed deposits of solid carbon, varying from 0.32% at a depth of 175 mm. to 3.50% near the inner surface of the shaft. This is due to a surplus of CO as compared with the equilibrium condition in the gases at this level which leads to the forming of CO_2 with simultaneous isolation of solid carbon; this reaction, though slow, is catalyzed by the iron oxide present. The alkali content of the sample varied from 3.16 to 9.82%, due to the alkalis present in the charge evaporating in the lower parts of the shaft; the vapors rise with the gases and condense on the cold surface of the upper zone of the shaft. The content of iron, calcium, and magnesia oxides showed an equal rise in the same direction. Another sample was taken from the hearth at a distance of 1700 mm. under the axle of the air tuyères. It was divided into 8 zones; zone 8, 20 mm. thick, forming the inner surface, showed a dense structure impregnated with metal. Zone 7, immediately following the outer one, 10 mm. thick, also had a dense structure and showed a black coloring. The three inner zones did not change their outer aspect. The carbon content fell from 0.31 in zone 8 to 0.02 in zone 6, rose to 1.16 in zone 5, and fell subsequently to 0.03 in zone 1. This can be explained by the entrance of carbon with the liquid iron into the outer zones and by the entrance of reducing gases after the molten iron is let out and up to the moment of a sufficient accumulation of slag. These gases enter through the joints of the lining. Owing to the penetration of basic slag, the CaO content attains 8.52% in zone 7 and 20.54% in zone 8, against an initial 1% in the brick. The alkali content falls from 2.60 to 0.50%, owing to solution in the slags and evaporation. The analysis of a series of samples taken from the inner surface at different levels of the shaft showed that the carbon and alkali contents fall at lower levels. Samples taken from the boshes demonstrated a very low content of carbon; the alkali content fell to some extent with rise in temperature. P.B. & E.S.

Chemicophysical properties of grog materials for steel casting ladles. Anon. Obshchesoyuznui Standard, OST., No. 6191; abstracted in *Referatkartei Silikatliteratur*, No. 223 (1934).—Standard specifications are given. M.V.C.

Concentration of Chasov-Yar clays. A. I. Kramarenko and M. Pukis. *Ogneuporui*, **3** [3] 216–23 (1935).—A flow sheet of the method and detailed data are given, showing that a concentrate can be obtained that possesses far better properties than any other refractory clays and which can be used for the production of high-grade refractories. This makes the method worth while though the costs are increased. P.B. & E.S.

Critical examination of tank blocks for the estimation of their probable stability. A. Möser. *Sprechsaal*, **68** [28] 442–44 (1935).—Besides corrosion tests, a knowledge of the structure must be considered in the examination of tank blocks. The demand for a fixed porosity value is insufficient for the valuation of the stability as it is not the porosity but the permeability which is decisive for resistance to corrosion. A simple determination of permeability by ascertaining the capillary action of the pores is given. The method, which serves for the differentiation between similar porosity values, can be employed as a criterion for the susceptibility to corrosion. It also permits a valuation of tank-block masses and their improvement. M.V.C.

De-airing of grog mixes. A. Möser. *Tonind.-Ztg.*, **59** [42] 507–508; [43] 521–22 (1935).—De-airing of grog mixes improves their properties in principle. Precautions to be taken to obtain faultless products are discussed. M.V.C.

Destruction of refractory brick in kilns. E. T. Richards. *Feuerungstechnik*, **22** [5] 49–52 (1935); abstracted in *Verre & Silicates Ind.*, **6** [13] 246 (1935).—Rapid variations in temperature are mainly responsible for the destruction of refractories. Grog are the most resistant, magnesite the least, and silica lies between. A more porous

and elastic block which is also a good conductor is more resistant; in brick which is a poor conductor of heat, a difference of 1000° may exist between the two faces. Among mechanical causes of destruction, crushing caused by expansion must be mentioned. Changes in structure in metallurgical furnaces are another cause of destruction. The thickness of refractories should not be exaggerated as it generally results in the premature fusion of the inside surfaces. M.V.C.

Digest of replies to the questionnaire on the durability of refractory materials in gas works. A. T. GREEN AND F. H. CLEWS. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 81–103 (1934).—A digest of the replies to the questionnaire on the durability of refractory materials in gas works sent out by the Institute of Gas Engineers is given. References are made to the subject of flaking in vertical retorts. The views concerning the cause of this trouble fall into four groups. The temperature fluctuations and high local temperatures which occur during the scurfing operation are held mainly responsible by some persons, while others regard the steep temperature gradient between the flue and the coking faces of the wall in this zone as the prime cause. Another theory advanced is that flaking is due to the action of alkali chlorides which react with the retort at this level and promote a tendency to spalling. A fourth states that the ash present in the scurf combines during the scurfing with the retort material under the influence of the local high temperatures to form a surface layer which is predisposed to spall off in thin flakes. With jointing cements, trouble through the use of unsuitable material is occasionally met with. This may be due to the cement fluxing, but more commonly it is the result of imperfect adhesion of the cement. In general, the composition of the cement follows closely that of the refractories, and the recommendations of the makers of the retort material are usually followed. Only in one instance is any specification as to the jointing material made. All of the replies emphasize the necessity for thin joints. H.E.S.

Effect of steatite additions to fireclay mixes. G. R. RIGBY AND A. T. GREEN. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 77–78 (1934).—A short note on the effect of the addition of steatite to fireclay mixes shows that, when suitably fired, the thermal expansion of the product between ordinary temperatures and 1000°C may be reduced one-half. Some decrease in refractoriness naturally results. H.E.S.

Experiments on the grading, porosity, and permeability to air of sillimanite brick. F. H. CLEWS AND A. T. GREEN. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 64–70 (1934).—The porosity and air permeability of sillimanite brick bonded with 10% ball clay are dependent on the grading of the raw mix and on the pressure used. A fact of considerable interest is that the size composition of the finest portion of the mix, *e.g.*, that passing through an 80-mesh sieve, can exert a considerable effect on the texture of the product as revealed by porosity and permeability measurements. In investigating the effect of pressure on the sillimanite mixes, it was found that an appreciable decrease in the proportion of the larger grains occurred. This raises the question of whether the grading to be adopted for machine-pressed products is necessarily the same as that for hand-tamped articles when minimum porosity and permeability are desired. H.E.S.

Extraction of alumina from Poshan bauxite by the soda-ash fusion method. CHENG-LUNG CHANG AND JUI CHOW. *Jour. Chinese Chem. Soc.*, **2**, 354–64 (1934); *Chem. Abs.*, **29**, 3117 (1935).—Laboratory-scale experiments were made to determine the optimum conditions for extracting Al_2O_3 by the soda-fusion method. The bauxite shale is roasted at 1100 to 1200° for 5 min., with the addition of 0.8 g. Na_2CO_3 and 0.23 g. $Ca(OH)_2$ per g. of shale. Desilication is effected by evaporating and cooking under 100 lb. pressure for 3 hr. The yield is 81 to 91% Al_2O_3. See also "Alumina—," p. 283.

Formation of magnesite metallurgical powder in the rotary kiln. V. V. BELOVODSKIĬ AND N. A. GOLUSHKO. *Ogneuporui*, **3** [3] 172–82 (1935).—Kilns used at the Satka magnesite plant are described. The speed of the decomposition of carbonate being a direct function of the coarseness of grain, the intensity of the firing process, and the time of the action of high temperature, the length of the sintering zone can be changed. Detailed data and a series of photomicrographs are given. P.B. & E.S.

Graphite stoppers. L. P. VLADIMIROV AND N. KARPOVA. *Metallurg*, **10** [4] 60–63 (1935). S.I.P.

High porosity silica brick. F. H. CLEWS AND A. T. GREEN. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 70–77 (1934).—The report on high porosity silica brick is occasioned by the possible field of usefulness for such products as high-temperature insulating materials. Small experimental blocks having a porosity of more than 55% and a refractoriness-under-load of 25 lb./sq. in. at about 1700°C have been prepared. It was also possible to prepare coherent test pieces of silica brick, having a porosity of 66%, by suitably grading the ganister and incorporating 40% by weight of similarly graded coke in the mix. H.E.S.

Improvements in the physical properties of silica brick. III. SANDFORD S. COLE. *Blast Fur. Steel Plant*, **23** [6] 429–30 (1935).—The relation of chemical composition and microstructure to other physical properties of silica brick is shown in tabular form. Lack of bond is the principal cause for weak brick. As fired porosity of quartzite decreases, the porosity of the fired brick is lowered. Usually a quartzite having a low-fired porosity will be strong and tough, and brick made from such a rock are strong and more resistant to abrasion. The size of silica grains making up the quartzite appears to bear a definite relationship to the firing behavior. With irregular-sized small grains, the porosity is lower and the strength is higher than with coarse, even-sized grain rocks. The rate of abrasion at room temperatures was found to be greater than at the higher temperatures. For Part II see *Ceram. Abs.*, **14** [7] 167 (1935); Part IV, *ibid.*, **14** [10] 248. E.J.V.

Industrial furnace refractories. T. E. WOOD. *Ind. Gas*, **13** [9] 14 (1935).—The properties of three types of insulating brick are given, one of which is a material especially developed for direct exposure in furnace atmospheres, provided there is no mechanical abrasion or direct flame impingement. Where an abrasive combustion can not be avoided, a facing material can be provided that will

withstand the direct contact of the flame. Insulating brick are made by the soft-mud process. Machining is done with emery grinders and silicon-carbide wheels. J.M.K.

Influence of carbon monoxide on grog materials. N. M. Lozinskiĭ and E. I. Ter-Mikaelyantz. *Ogneuporui*, **2** [12] 18–20 (1934).—Investigations on the influence of carbon monoxide on refractories have been made by the Ukrainian Refractories Institute. Pure carbon monoxide, obtained by thermal decomposition of formic acid and cleaned by washing in alkaline solution of pyrogallol and in potassium lye and dried afterward, was taken. The sample was introduced into a furnace and heated to 475° (the temperature at which carbon evolves according to the reaction $2CO \rightarrow CO_2 + C$ at the greatest rate). Carbon monoxide was introduced in the heated furnace at a rate of 0.5 l./hr. To investigate the catalytic action of iron compounds, tests were undertaken with magnesite, hematite, metallic-iron sawdust, and pyrite, the exposure to the influence of CO taking 5 hr. with every sample. Their catalytic activity falls in the order named. To obtain data on the influence of CO on refractories produced under different technical conditions, a series of samples from 40% refractory clay and 60% grog were prepared, with the above-named metallic additions in a proportion of 3 to 6%. The samples were fired at 1000, 1100, 1200, 1300, and 1400°C. Samples made with more coarse additions disclosed a higher rate of corrosion. Those fired at higher temperatures disclosed a much greater resistance to the action of CO than those fired at lower temperatures; this is especially true for the temperatures of 1300 and 1400°. The samples fired under 1200° crumbled away into powder after the investigation, and those fired at higher temperatures fell into large pieces, which is explained by the growth of mechanical strength resulting from sintering. The resistance of refractories can be improved by additions of 5 to 10% of meal from amorphous quartzites, these giving better results than a 100° rise in temperature. Samples prepared in this way did not corrode under the influence of carbon monoxide during 120 hr. A microchemical analysis of the samples tested demonstrated that the iron oxides do not reduce to the metallic state which proves that the catalyzing action belongs not to metallic iron but to its oxides. P.B. & E.S.

Insulation and control of open-hearth furnaces. William C. Buell, Jr. *Mining & Met.*, **16** [345] 398 (1935).—Thermal effects developed in 12- and 18-in. roofs of silica brick, when insulated to varying thermal resistances, are shown by diagrams. Common insulating materials are divided into five groups based on their principal physical characteristics of resistance to heat flow, crushing strength, and resistance to fusion, shrinkage, or disintegration at high temperature. Control of furnace operation, less the metallurgical factors, is divided into seven items, all of which have a material effect on quality of operation. Two methods of control, manual and instrumental, are analyzed as to their effect on the several operating items. E.J.V.

Jointing cements. F. H. Clews, H. Booth, and A. T. Green. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 55–64 (1934).—This report describes the development of a test for gaging the behavior of cements during the heating-up and operation of an installation. In principle, the test measures the expansion or deformation of two $^1/_4$-in. joints between three brick blocks while they are subjected to a high load. The breaking strength of the joints can be determined subsequently. The method has been applied to a variety of synthetic cement mixtures with a silica base. H.E.S.

Lightweight refractory concrete. N. J. Kent. *Heat Treating & Forging*, **21** [7] 343 (1935).—The properties of an alumina base refractory, capable of withstanding temperatures up to 2400°F, are given. This material is handled like ordinary concrete and may be poured into any shape. Fuel saving for intermittently fired furnaces and reduced heating-up time result from its lower heat-storage capacity compared with fireclay brick. J.M.K.

Linear changes in silica brick in the process of firing. I. S. Kainarskiĭ and M. I. Kostomarov. *Ogneuporui*, **2** [12] 14–18 (1934).—An investigation has been undertaken with the aid of a Hirsch-Hecht device which proved to be appropriate for the investigation of the behavior of silica in the firing process, of the changes taking place in its mass, and of the influence of different composition of the charge and of mineralizing additions. It was found that β to α transformation of quartz is the most perilous; therefore in the interval 500 to 650° the temperature rise must be slowed down; at higher temperatures, up to 1200°, it can be accelerated. Over 1200°, the volume of the brick begins to increase, owing to the beginning transformation of α-quartz to modifications with a low specific weight; therefore from this point the temperature rise must be very slow, and it is necessary to have a low-viscous flux medium at this temperature in the ware being fired. The cooling process can be conducted rapidly to 300°, because the $\beta \rightarrow \alpha$ transformation, owing to a low amount of quartz, does not give a marked volume effect. Further cooling must be carefully done. It is a mistake to apply quick cooling beginning with 1400°, because this leads to an interruption of the transformation that takes place in the brick. The cristobalite and tridymite effects are very marked during the cooling process. P.B. & E.S.

Magnesite-dolomite industry of Canada. K. C. Rowe and A. J. McBain. *Can. Mining Jour.*, **56** [8] 309–14 (1935).—Magnesite was discovered in the Grenville district of Quebec in 1900, but active production did not begin until 1915. Dwindling markets after the war brought about intensive research work, resulting in new and larger markets for the Canadian Refractories Co. The deposit is not magnesite but an intergrowth of dolomite and magnesitic dolomite and is mined by the bench system of quarrying. Products include 12 magnesian refractories, 7 chrome-base refractories, and 2 silica refractories made from Canadian materials and South African chrome. G.M.H.

Malleable furnace refractories. L. C. Hewitt. *Amer. Foundryman's Assn.* [Preprint], No. 35-13 (1935).—Recent developments in malleable furnace refractories are reviewed. Bung brick have been improved, particularly in respect to spalling resistance. Bung service factors and brick design are discussed. Side-wall life has been improved through the use of super-fireclay brick and high-temperature mortar. Tapout block of a super-fireclay type have also come into use. Firebrick bottoms laid

with cold set, high-temperature cement are rapidly gaining favor. H.E.S.

Manufacture of half-acid refractories of high quality. P. P. BUDNIKOFF. *Chem. Obzor*, **10**, 25–27 (in English 28) (1935); *Chem. Abs.*, **29**, 5238 (1935).—Half-acid refractories possess a sufficient heat and chemical resistance to satisfy the requirements of the iron and steel, coke, and petroleum industries. They are divided into (1) silico-clay (from aerial clay), (2) half-acid fire clay, made from clay containing fine quartz, and (3) silico-fire clay, from clay with chamotte and sand added. In all cases they contain not over 30% Al_2O_3 and at least 65% SiO_2. In refractories for the highest parts of blast-furnace shafts, the mechanical strength is increased by the addition of crystalline quartz sandstone. Suitable binding clay contains at least 32% Al_2O_3 and not over 1.5% Fe_2O_3. The firing temperature is not below cone 13.

Nonplastic ceramic masses. W. DAWIHL. *Keram. Rund.*, **42**, 547–48 (1934); *Chem. Abs.*, **29**, 567 (1935).—Methods of increasing plasticity and the processing of nonplastic refractories are discussed.

Practical boiler-furnace refractory examination. A. G. AREND. *Cheap Steam* [London], **28** [6] 105–107 (1934); abstracted in *Sprechsaal*, **68** [31] 484 (1935).—The part played by slag, flue-gas ash, reducing atmosphere, and composition in the corrosion of refractories is discussed. M.V.C.

Production of aluminum oxide from Tikhvin bauxite by the combined Penyakov methods. V. P. IL'INSKIĬ, A. F. SAGAIDACHNUIĬ, AND G. P. MATVEEV. *Trans. State Inst. Applied Chem.* [U.S.S.R.], No. 16, pp. 60–70 (1932); *Chem. Abs.*, **29**, 298–99 (1935).—The procedure is based on the two methods of Penyakov (Ger. 80,063, issued in in 1893; Ger. 93,952 and 247,763, and Russ. 69,498, issued in 1916) and on the reaction $Na_2SO_4 + CaCO_3 + 4C = Na_2CO_3 + CaS + 4CO$; $Al_2O_3 + Na_2CO_3 = 2AlNaO_2 + CO_2$; $Fe_2O_3 + Na_2CO_3 = 2FeNaO_2 + CO_2$. A yield of 90% Al_2O_3, containing a maximum of 0.09% SiO_2 and free from Fe, was obtained from a mixture of 20 g. Tikhvin bauxite (Al_2O_3 42.29, Fe_2O_3 25.84, and SiO_2 15.45%), 21 g. Na_2SO_4 (20% excess), 15 g. $CaCO_3$ (20% excess), and 11 g. C (70% excess) by electrical heating at 880 to 920° for 3 hr. in a graphite or graphitized crucible, leaching out the porous melt at 100° for 15 to 20 min., precipitating $Al(OH)_3$ with CO_2 at 60 to 90°, and igniting.

Progress report of other work of interest to gas engineers. ANON. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 78–79 (1934).—In hot patching, the main requirements appear to be a surface sufficiently rough for the plastic clay to "key" into the irregularities, sufficient plasticity of the clay, and sufficient strength in the suddenly heated clay for initial adhesion to be maintained. Work is being continued on (1) jointing cements, (2) factors influencing the texture of refractory materials, and (3) the influence of different alkali salts on silica and fireclay products. Experiments with a view to standardizing a refractoriness-under-load test are in progress. The size of the test piece and the loading are under consideration. Other investigations, such as the slagging of refractory materials and the mechanical properties of silica brick and fire brick, are being made. H.E.S.

Properties and applications of modern refractories. W. F. ROCHOW. *Chem. Met. Eng.*, **42** [2] 76 (1935).—The chief tests applied to refractories to determine their adaptability for a certain service include chemical analysis, porosity, fusion point (P.C.E.), thermal expansion and permanent volume change, strength, resistance to rapid temperature changes, thermal conductivity, heat capacity, and contradictory properties. A general discussion is included on the physical properties and applications of silica brick, fireclay brick, high-alumina refractories, basic refractories, and insulating brick and lightweight refractories. M.C.S.

Properties of refractory special bodies. MARCEL LÉPINGLE. *Ind. chim. belge*, **5**, 443–47 (1934); abstracted in *Chem. Zentr.*, **i**, 1753 (1935).—Data on the composition and properties of silicon-carbide brick and brick with a high alumina content are given. M.V.C.

Pure highly refractory oxides, a new German ceramic industrial material for chemical apparatus. E. RISHKEVICH. Presented at the Dechema, 1935; abstracted in *Glashütte*, **65** [30] 458 (1935).—The new ware, manufactured from pure highly refractory oxides, such as Al_2O_3, BeO, ZrO_2, MgO, ThO_2, etc., possesses very high refractoriness, a complete gas-tightness, and an extraordinary resistance to chemical attack. The application of the ware is discussed. M.V.C.

Refractories for foundry use. W. J. REES. Presented at 32nd Annual Conference of the Inst. of Brit. Foundrymen; *Mech. World*, **98** [2536] 121–22 (1935).—Cupola relining is probably the most important operation in foundry maintenance. The available materials have different properties which must be clearly understood if the best use is to be made of them. R. discusses effect of heating rate, vitrification and strength, and jointing cements. E.J.V.

Refractoriness and its determination. F. H. CLEWS AND A. T. GREEN. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 8–30 (1934).—A critical review of the methods for refractoriness-under-load tests is given. The American practice is to determine the behavior of a refractory material under load on heating to a prescribed temperature, which is then maintained for a definite period. Two standard-sized brick are so treated in the same furnace. In the German and French methods, a small specimen is heated under load until failure occurs. The size of the specimen described in the German industrial specification (DIN 1064) is a cylinder measuring 50 x 50 mm., while in France still smaller test pieces are employed. The practice in England is similar to that followed in Germany, but larger test pieces are used ($3\frac{1}{2}$ x 2 x 2 in.). Two main issues are thus apparent: (1) Should an under-load refractoriness test be preferably carried to the temperature of complete failure or merely maintained at a value comparable to that at which the material will be put into service? (2) What is the best size of test piece? Closely connected with this latter question is the rate of rise of temperature to be adopted. Other variations in the procedure for carrying out the test, such as the value of the load, the method of measuring the temperature and recording the expansions or subsidence of the test piece, although of great importance, are probably of subsidiary interest. In the type of test where the temperature is raised until the specimen fails, the data of chief importance

are (1) the temperature at which softening commences, (2) the temperature when softening accelerates, and (3) the temperature of failure. H.E.S.

Refractoriness-under-load test. F. H. CLEWS, A. GREEN, AND A. T. GREEN. *Refrac. Materials Joint Sub-Committee, 25th Rept.*, pp. 30–41 (1934).—The experimental work relates entirely to the type of test where failure of the specimen results, and it is shown that the recorded temperature of failure may be increased by as much as 100°C when the test piece is heated at 15°C/min. when compared with 3°C/min. This refers to test pieces of 4 sq. in. cross-section. Similar effects are obtained by varying the area of cross-section of the test piece. Evidence is given to show that variation in the temperature gradient within the test piece is largely responsible for these divergent results. Experiments are also described which show how the form of the temperature-deformation curve may be distorted by not allowing for the expansion of the supports and thrust blocks in the furnace. When this correction is disregarded, the temperature of initial softening may appear as much as 300°C in excess of the true value. H.E.S.

Refractory cement for hot repairs of coke ovens. G. V. KUKOLEV AND A. V. AMERIKOV. *Ogneuporui*, **3** [3] 187–95 (1935).—A German refractory cement, Gitempit, was investigated. It gave unsatisfactory results in service. It consists of a mixture of plastic refractory clay, finely ground quartz, and soluble glass. A cement was prepared by the authors from 5% of Ocheretino quartzite, 30 to 35% of Chasov-Yar sand or Kuteinikovo quartzite, 10 to 15% of Chasov-Yar clay, and 3% of the by-product from obtaining alumina from kaolin by the alkaline method (chemical analysis: 26.20 SiO_2, 11.08 Al_2O_3, 31.69 CaO, 0.43 MgO, ignition loss 20.13, and alkalis 10.47%); 1.8 to 2.45% of Na_2O in the form of soluble glass was also added to the dry mass. The best granulometric composition of the mass and the method of preparing it were investigated. The cement is being produced at an experimental plant under the name of Uniok. P.B. & E.S.

Refractory plants of the Vostokostal iron and steel works in 1934. P. I. POTEMKIN. *Ogneuporui*, **3** [3] 164–72 (1935).—Characteristics of the work and the technological processes of the refractory plants of the Ural iron and steel works are discussed. P.B. & E.S.

Saving gas fuel by use of insulation refractory materials. ROY P. WILSON. *Amer. Gas Assn. Proc.*, 702 (1934).—The heating-up tests on two small gas-fired oven furnaces are described in detail. The time saved, due to the use of lightweight refractory, varied from 64 to 68%. The gas-fuel savings varied from 41 to 46%. J.M.K.

Semidry pressing of grog brick. KLESPER. *Tonind.-Ztg.*, **59** [30] 381–82 (1935).—When manufacturing semi-dry-pressed brick, the mix (1) must be free from knobs and lumps, (2) must have a moisture content of 7 to 9% which must be distributed uniformly in the mix, and (3) should not contain any air. Details are given. M.V.C.

Silica brick for coke ovens. K. KATO. *Jour. Fuel Soc. Japan*, **14**, 32–33 (in English) (1935); *Chem. Abs.*, **29**, 5236 (1935).—Silica brick manufactured in Japan have a lower SiO_2 content and a higher Fe_2O_3 content. The presence of an appreciable amount of Fe in quartz favors the conversion of quartz into tridymite; otherwise the formation of cristobalite is accelerated. The true specific gravity of Japanese silica brick is 2.35 or more.

Sintered corundum. ANON. *TZ. prakt. Metallbearbeits.*, **44**, 350–51 (1934); abstracted in *Chem. Zentr.*, **i**, 612 (1935).—A short description of properties of sintered corundum is given. M.V.C.

Spalling resistance of refractory materials. P. S. MAMUIKIN. *Ogneuporui*, **3** [3] 199–202 (1935).—The theoretical considerations of the problem made by Norton in Refractories (*Ceram. Abs.*, **11** [1] 40 (1932)) and Endell (*ibid.*, **12** [8] 301 (1933)) are reviewed. M. concludes that spalling resistance can be expressed by a definite number and that for most refractory materials the method of twisting is the most appropriate. P.B. & E.S.

Survey of insulation practice. C. W. PARMELEE AND A. E. BADGER. Presented at Third Conference on Glass Problems, Urbana, Ill., June, 1935; *Glass Ind.*, **16** [9] 274–77 (1935).—A summary of replies to a questionnaire which was submitted to the glass trade is presented. E.J.V.

Synthesis of spinels. A. BAZILEVICH. *Mineral Suir'e*, **9** [9] 25–30 (1934).—Conditions necessary for the formation of spinels ($MgO{\cdot}Al_2O_3$, $MgO{\cdot}Cr_2O_3$, $MgO{\cdot}Fe_2O_3$, and $2MgO{\cdot}SiO_2$) from pure oxides and raw materials were studied. Aluminous spinel can be used as a refractory. Products with an incipient softening at 1700°C may be obtained by electric fusing. Attempts to obtain spinel-forsterite refractories with a magnesite base and various alumino-silicates were unsuccessful. M.V.C.

Theory of firing refractories. ANON. *Ogneuporui*, **3** [3] 182–87 (1935).—A section of the Scientific Engineering Technical Society meeting at the Refractories Institute at Kharkov discussed the theory of firing of Starostin (*Ceram. Abs.*, **14** [5] 124 (1935)). It was concluded that the firing and cooling of silica brick can be accelerated. P.B. & E.S.

Thermal investigation of the reactions between the component parts of the lime-soda-bauxite mixture (in the production of aluminum). D. KH. AVDALIAN. *Trans. State Inst. Applied Chem.* [U.S.S.R.], No. 16, pp. 106–22 (1932); *Chem. Abs.*, **29**, 299 (1935).—The following conclusions are based on the experimental study and literature data. All chemical interactions of the constituents of the reaction mixture leading to the formation of $Al_2O_3{\cdot}Na_2O$ and $CaSiO_3$ are completed at about 1000°. Temperatures above 1000° lead to the formation of H_2O-insoluble compounds and the reduction of Al_2O_3 yield. The curves for thermal decomposition of kaolin show that at 600° kaolin separates H_2O with molecular decomposition and at 950° undergoes an internal conversion with the liberation of heat, $Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O = Al_2O_3{\cdot}SiO_2 + SiO_2 + 2H_2O$: (*a*) kaolin reacts with CaO at 500°, giving $CaSiO_3$ and (*b*) at 600° with Na_2CO_3, giving Na_2SiO_3; (*c*) Na_2SiO_3 reacts with CaO at 500°; (*d*) the reaction between Al_2O_3 and CaO begins at 950 and ends at 1600°; (*e*) contrary to some authors, the reaction of internal conversion (Al_2O_3) at 900 to 1000° was not observed; (*f*) the reaction of CaO with amorphous SiO_2 takes place at 500° and with quartz at 700°. The reaction of kaolin and CaO at 500° is incomplete because, on adding Na_2CO_3 and heating to 600°, Na_2SiO_3 is formed. Hence the break at 950° on the curve indicates an internal molecular conversion of $Al_2O_3{\cdot}SiO_2$

and therefore the scheme of molecular decomposition of kaolin, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O = Al_2O_3 + 2SiO_2 + 2H_2O$, proposed by Tammann and Pape (*Ceram. Abs.*, **2** [11] 266 (1923)) is considered in contradiction with experimental data. The interpretation of the reaction between kaolin and CaO in the second process of Penyakov (Russ. 69,498, Class 12:I), kaolin + $3CaCO_3 = Al_2O_3CaO + 2CaSiO_3 + 2CO_2 + 2H_2O$, is untenable because the reaction between Al_2O_3 and CaO is completed at considerably higher temperature (1600°) than is given in the patent and should be $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O + 2CaCO_3 = 2CaSiO_3 + Al_2O_3 + 2H_2O + 2CO_2$. For lime-soda-bauxite mixtures the optimum temperature is 1000°. By substitution of CaO for $CaCO_3$, the temperature of heating can be reduced, and the quantity of SiO_2 dissolved in the solutions is decreased.

Unfired refractory products. A. KARKLIT. *Technika*, No. 53 (1934); abstracted in *Referaikartei Silikatliteratur*, No. 515 (1934).—Details of manufacturing unfired refractories from a mixture of refractory clay, grog, and quartz sand (proportion: 30:55:15) and a solution of sulfite cellulose waste liquor are given. M.V.C.

BOOKS

Alumina from Poshan bauxite. CHENG-LUNG CHANG AND KUANG-HSUI HSIEH. *Golden Sea Research Inst. Chem. Ind.* [China] *Bull.*, No. 4, 19 pp. (1933); *Chem. Abs.*, **29**, 3117 (1935).—This deposit is properly an aluminous shale, samples showing 50.82 and 51.64% Al_2O_3. It is recommended to concentrate the Al_2O_3 by roasting with Na_2CO_3 and CaO, with subsequent desilication by treating with boiling H_2O and CO_2. See also *Ceram. Abs.*, **13** [8] 210 (1934).

Failures and troubles in open-hearth manufacture and measures to combat them. N. S. MIROSHNICHENKO. Chief Editorial Office of Literature on Ferrous Metallurgy, Moscow, 1935. 44 pp. Price 40k. The brochure is of practical interest to refractories manufacturers and metallurgists. Thirty-six cases are reported. S. I. PERKAL

Physical fundamentals of heat transfer. Vol. I. A. A. GUKHMAN. All-Union Institute of Heat-Hydro-Energy Equipment (V.I.T.G.E.O.) Vol. 1. State Energy Pub. House, Leningrad, Moscow, 1934. 316 pp. Price 8R. This volume discusses the theory of similarity and its application in an introduction and the eight chapters as follows: (1) physical thermal technique, its methods and problems, (2) modern ideas of heat exchange, (3) basis and mechanism of spreading heat energy in a material medium, (4) theory of similarity, (5) nonstationary heat state of a solid body, (6) forced motion of liquid, (7) perpetually forced motion in materials, (8) heat exchange in materials, (9) heat transfer from the exterior, and (10) free motion. Scientific contributions such as this are useful in solving common industrial problems. S. I. PERKAL

Production of silica brick from crystalline quartzites, theory, and practice. N. V. SHVEZOV. ONTI, Sverdlovsk, Moscow, Leningrad, 1934. 154 pp. Price 2R 75k. The book is in two parts. The theoretical part is a compilation from the books of R. Niederleutner, Unbildsame Rohstoffe Keramischer Massen, and I. F. Ponomarev, Refractory Materials (*Ceram. Abs.*, **11** [4] 251 (1932)). The second part presents characteristics of Ural raw materials and describes the practice of silica brick production at the Zlatoust works.

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Thermal decomposition of alunite. TAO TSONG. *Golden Sea Research Inst. Chem. Ind.* [China] *Bull.*, No. 13, 13 pp. (1934); *Chem. Abs.*, **29**, 3117 (1935).

PATENTS

Acidproof cement. HODOGAYA SODA K. K. (Shôichirô Nagai, inventor). Japan. 109,443, Jan. 31, 1935; *Chem. Abs.*, **29**, 4543 (1935).—Siliceous clay or like material that contains much soluble silicic acid is heated with a concentrated NaOH solution and filtered. The residue is washed and heated to make the remaining silicic acid insoluble and then is treated with H_2SO_4, magnesia being dissolved. The cement is prepared by mixing the last residue with the first filtrate.

Aluminum oxide. SIEMENS-SCHUCKERTWERKE A.-G. (Reinhold Reichmann, inventor). Ger. 560,575, Feb. 8, 1935; *Chem. Abs.*, **29**, 5229 (1935).—Tools and other objects are made by molding and sintering pure Al_2O_3 at temperatures above 100° in surroundings free from C. The product is a hard solid mass suitable for polishing, grinding, etc.

Checker brickwork construction for regenerator furnaces. BONNYBRIDGE SILICA & FIRECLAY CO., LTD., AND W. MCBRYDE. Brit. 433,762, Sept. 4, 1935 (Feb. 26, 1935).

Furnace construction. J. E. ANDERSON (Plibrico Jointless Firebrick Co.), U. S. 2,011,701, Aug. 20, 1935 (Feb. 5, 1932). L. H. HOSBEIN (M. H. Detrick Co.), U. S. 2,012-429, Aug. 27, 1935 (March 17, 1933).

Hot tops for ingot molds. W. M. CHARMAN. Brit. 433,345, Aug. 28, 1935 (Aug. 18, 1934).

Process for manufacturing sintered magnesia and refractory materials containing it. K. KONOPICKY. Brit. 432,303, Aug. 8, 1935 (April 19, 1933).

Refractory article. K. E. BUCK (Ross-Tacony Crucible Co.). U. S. 2,013,625, Sept. 3, 1935 (March 29, 1933). A refractory article of manufacture comprises refractory aggregates having a bond consisting of residual carbon and having dispersed throughout the refractory article a metallic substance selected from a group of substances consisting of metals, metal alloys, and metalloids to provide vitreous protective coatings.

Refractory brick. DIDIER-WERKE A.-G. Ger. 606,495, Dec. 4, 1934; *Chem. Abs.*, **29**, 5244 (1935). Addition to 594,000, March 9, 1934. The method of 594,000 is used for making brick from ground insulating chamotte, mineral binding agent, and water. Thus, a chamotte made from clay, sawdust, and water is ground and mixed with lignite dust and sulfite waste. The resulting paste is molded and fired.

Refractory linings for furnaces and brick therefor. STERLING METALS, LTD., AND D. J. GASCOIGNE. Brit. 432,512, Aug. 8, 1935 (July 9, 1934).

Refractory linings for rotary melting furnaces. W. SCOTT. Brit. 432,213, Aug. 8, 1935 (Jan. 23, 1934).

Refractory products. VICTOR MORITZ GOLDSCHMIDT.

Ger. 607,591, Jan. 3, 1935; *Chem. Abs.*, **29**, 4146 (1935); addition to Ger. 582,893, Aug. 24, 1933. The method of 582,893, for making fireproof stone by heating granular olivine and MgO, etc., is modified by using granular olivine containing less than 10% (preferably not more than 5%) of Mg hydrosilicate, *e.g.*, serpentine, and poor in $Fe_4(SiO_4)_3$.

Terra Cotta

Acid-stable vitrified tile. R. SELZER. *Tonind.-Ztg.*, **59** [38] 462–63 (1935).—Acid-stable vitrified tile are similar to feldspar porcelain in their composition. The composition, working, and firing are briefly discussed. M.V.C.

Effect of firing temperature on frost stability of clays. MARTHA ANDRÄ. *Tonind.-Ztg.*, **59** [44] 531–32 (1935).—Investigations showed that the danger of frost for roof tile is considerably lowered by a higher firing and additions of lean clay to the mix. Both methods can be used but only within certain limits because they increase the water permeability of tile. M.V.C.

Engobes. WOLFGANG KAUFMANN. *Tonind.-Ztg.*, **59** [46] 558–59; [47/48] 573–74; [49] 587–88 (1935).—Products to be coated with engobe should not be fired at too low a temperature. Every color tone may be obtained, provided the right kind of engobe clay is used. The pigment must be finely distributed. Engobe clays vitrify easily and yield the required colors rapidly. Plastic engobe clays coat little plastic bodies without stresses when the coat is sufficiently thin. M.V.C.

Manufacture of salt-glazed stoneware pipes and fittings. I–III. A. COULHON. Translated in *Brit. Clayworker*, **44** [518] 76; [519] 106–108; [520] 138–39 (1935); see *Ceram. Abs.*, **14** [9] 217 (1935). R.A.H.

PATENT

Ceramic masses. FELIX SINGER. Ger. 609,806, Feb 27, 1935; *Chem. Abs.*, **29**, 5243 (1935).—Objects resistant to alkalis and alkali compounds are made from masses of the compound $ROAl_2O_3$, the radical RO consisting of two or more different bases. The mass is fired under conditions preventing the formation of spinel crystals of size above 1μ. One of the constituents may be present as sulfate or chloride. In examples, the constituents may be (1) Al_2O_3 52, magnesite 38, and $BaCO_3$ 10%; (2) Al_2O_3 51, magnesite 38, and $BaSO_4$ 11%.

Whiteware

California pottery made in modern plant. ANON. *Ceram. Ind.*, **25** [3] 131–32 (1935).—The Pacific Clay Products, Inc., producer of structural clay products, is also producing distinctively shaped pottery in pastel shades. The strong stoneware body is prepared by carefully controlled mixtures of five California clays. A gas-fired tunnel kiln with automatic temperature control is used. A rapid cooling immediately after leaving the firing zone produces a desirable annealing condition. Illustrated. E.J.V.

Mineral plastics in the porcelain field. ANON. *Ind. Bull. of Arthur D. Little, Inc.; Ceram. Ind.*, **25** [3] 128 (1935).—Among the materials available for mineral plastics and machineable blanks are (1) lava, machined and kiln-hardened steatite; (2) Alsimag, a double silicate of aluminum and magnesium which may be extruded or pressed; and (3) chemically pure oxides of aluminum, magnesium, and beryllium. Lava has high resistance to uses which require a combination of heat, chemical abuse, and mechanical erosion. Alsimag is very strong after heat treatment and an excellent insulator, having an important place in the high-frequency field. E.J.V.

Nature of the glass phase in heated clay materials. I. Common clays. G. R. SHELTON. *Jour. Amer. Ceram. Soc.*, **18** [10] 289–96 (1935).

Properties of porcelain insulators. Y. MURATA. *Jour. Inst. Elec. Engrs.* [Japan], **54**, 746–52 (1934); *Chem. Abs.*, **29**, 567 (1934).—Breakdown voltage with surge and static voltages and other characteristics for commercial porcelain insulators are given.

Rational conditions for drying telegraph and telephone insulators. A. I. AVGUSTINNIK AND P. M. BRUSLINSKAYA. *Keram. i Steklo*, **11** [5] 35–38 (1935).—Tables and diagrams show the results of the study. M.V.C

BOOKS AND BULLETINS

Chemical stoneware for special purposes. FELIX SINGER. *Chemistry & Industry* (extended reprint), 8 pp. Nov. 23, 1934.—The general limits in composition of stoneware and porcelain are as follows:

	Stoneware (%)	Porcelain (%)
Clay substance	30 to 70	42 to 66
Quartz	30 to 60	12 to 30
Feldspar	5 to 25	17 to 27

The development of physical properties of stoneware masses for twelve years is shown as follows:

	1921	1933
Compression strength (kg./cm.^{2})	5816	8210
Tensile strength (kg./cm.^{2})	116	528
Bending resistance (kg./cm.^{2})	416	953
Elastic modulus (kg./mm.^{2})	4175	4175
Torsional resistance (kg./cm.^{2})	251	323
Impact strength (cm. kg./cm.^{3})	1.9	4.97
Abrasion test (loss in cm.^{3})	3.0	0.6
Water absorption (%)	0.5	Nil
Coefficient of expansion	4.1×10^{-6}	0.15×10^{-6}
Thermal conductivity (kg. cal. m.$^{-1}$ h.$^{-1}$ c.$^{-1}$)	1.35	3.95

S. I. PERKAL

Lomonossov Porcelain Plant, 1917–1932. V. N. SOKOLOV. State Chem.-Tech. Pub. House, Leningrad, 1932. 16 pp. Price 30k. An outline is given of the history and present and future prospects of this plant, established in 1744. It is the forerunner of the entire Russian porcelain industry. Its history is, in fact, the history of the development of Russian ceramics and is of great significance for an investigation of the Russian art industry in general. The high quality and art treatment of the chinaware of this plant has made it renowned. See also "Rus-

sian chinaware: a microscopical study," *Bull. Amer. Ceram. Soc.*, **14** [3] 101–104 (1935). S. I. PERKAL

Standards for Porcelain and Glass Electro-Insulating Materials. Compiled by N. SLYUSSAREV. All-Union Comm. of Stand. State Pub. House of Standardization, Moscow and Leningrad, 1935. 140 pp. Price 4R 50k. This book has three sections: (1) dealing with general official All-Union standards ("OST"), *e.g.*, international electric units, scales of nominal current strengths of electrical apparatus from 5Å to 5000Å, nominal strains of three-phase currents, light units, general methods of testing electrical articles for electrical, thermal, and mechanical strength, fire resistance, refractoriness, etc.; (2) 20 standards referring to porcelain and electro-insulating materials and articles; (3) 10 standards for glass electro-insulating materials and articles as follows: (*a*) packing of glass articles, (*b*) electro-armature glass, (*c*, *d*) machine-made window Fourcault glass, (*e*) jars and glass parts for cells, (*f*, *g*, *h*) jars for elements of the Herkules, Le Klanché, and Meydinger types, (*i*) common window glass (hand-made), and (*j*) incandescent lamps.

This book, together with the volume of standards in the glass and porcelain faience industries, see *Ceram. Abs.*, **14** [4] 92 (1935), is of special value to those interested in national and international standardization in the glass and whiteware industries. S. I. PERKAL

PATENTS

Ceramic articles. L. H. BOWN (Buffalo Pottery Co.). U. S. 2,013,740, Sept. 10, 1935 (March 7, 1932); original U. S. 1,849,272, March 15, 1932 (April 15, 1931). A fired article of chinaware has a thin wall formed of overrunning sheet-like layers of a china mix of the same nature and characteristics but of different colors united face to face while plastic and flush with one another at the junctions, the color of each layer being uniform throughout the thickness of the layer, the faces of the layers overrunning in the interior of the face of the chinaware and merging in a flush relation with one another at the points of overrunning, one of the layers at any overrunning edge having a feather edge providing a flush junction of the surfaces where the layers overrun.

Ceramic objects. STEATIT-MAGNESIA A.-G. Ger. 608,-949, Feb. 4, 1935; *Chem. Abs.*, **29**, 5243 (1935).—A mixture of clay or kaolin and $BeSiO_3$ free from quartz or feldspar is molded and fired. An alkali-free flux, except $MgSiO_3$, may be added.

Electrical insulators. STEATIT-MAGNESIA A.-G. Brit. 429,730, June 19, 1935 (Sept. 27, 1933).

Tile and fixture display apparatus. N. C. BUTLER (National Tile Co.). U. S. 2,011,843, Aug. 20, 1935 (July 13, 1934).

Equipment and Apparatus

Accelerated drying of products from plastic clay without adding nonplastic material. A. SELIVANOV. *Stroitel. Material.*, No. 3, pp. 6–9 (1935).—In an artificial drier equipped with a blast and an exhaust fan, permitting control of the process in both the hot and moist chambers, a considerable decrease of damaged output was obtained. Cracks in the brick disappeared completely, the drying was homogeneous, less fuel was needed, and the drying process took 3 to 4 days instead of 8 to 10. Further improvements are foreseen. P.B. & E.S.

Air conditioning in spraying rooms. CARL W. SANDERS. *Ind. Finishing*, **11** [9] 17–22 (1935).—S. advocates enclosed, air-conditioned spray booths served by continuous conveyers taking the sprayed articles directly to the drying ovens. This will achieve as good or better results with less expense than air conditioning the entire floor or building. Illustrated. J.L.G.

Counter-current tunnel drier. K. A. NOKHRATYAN AND M. I. LAPOVOK. *Stroitel. Material.*, No. 3, pp. 11–29 (1935).—Results of tests undertaken at an experimental brick plant are given. P.B. & E.S.

De-airing of clay products. J. O. EVERHART. *Refrac. Jour.*, **10** [11] 498 (1934).—The de-airing of stiff-mud and dry-press clay products is discussed. De-airing greatly increases the workability of stiff-mud bodies, and ware produced with it is usually much improved over the ordinary ware. De-airing reduces blistering, laminations, and tearing and usually increases the dry and fired strength. De-aired clay usually matures at a somewhat lower temperature than the clay which is not so treated. M.C.S.

De-airing dry-press refractories. ANON. *Brick Clay Rec.*, **87** [2] 52–53 (1935).—The first commercial installation of a dry-press de-airing unit at the Goose Lake plant of the Illinois Clay Products Co., near Joliet, Ill., claimed to produce brick having greater density, reduced porosity, and increased strength, is described in detail. Illustrated. E.J.V.

Defects in bodies due to extruding presses. ANON. *Tonind.-Ztg.*, **59** [55] 653–55; [56] 668–70; [57] 680–81 (1935).—Most shaping defects in ceramic products produced by uneven pressure are due to mechanical causes and unsatisfactory operation of extruding machines. M.V.C.

Development and status of large X-ray picture methods in testing materials. A. HERR. *Messtechnik*, **11** [7] 129–31 (1935).—The efforts to examine large areas of objects to be subjected to X-ray examination at one time instead of taking several smaller exposures are discussed. Voltages from 400,000 to 600,000 volts are applied. The equipment and procedure are described. M.H.

Hydrometer method of determining grain size. W. PETERSEN. *Sprechsaal*, **68** [27] 423–27 (1935).—The theoretical principles of the Casagrande process for determining the grain size of soils, by measuring the specific gravity of deposits of fine-grained solids, are explained. The special hydrometer used is described, and the considerations of the effect of temperature and the removal of the liquid through the hydrometer are explained by the valuation of the hydrometer readings. By the use of a "monogram," which is also suitable for other methods of grain-size determination and simple graphic representations, the calculation of the grain size and the constituents from the hydrometer readings is simplified and shortened. Testing the hydrometer method by the pipet method on fine-grained ceramic raw materials (kaolin) showed excellent agreement of both methods. The hydrometer

method is recommended for grain-size determination of ceramic raw materials because of its simplicity and low cost. M.V.C.

Increasing the output of excavators by a simplified control method. DEMAG A.-G. *Eng. Progress*, **16** [6] 156 (1935).—The system of universal control employed on a Demag excavator to speed up the working cycle is described and illustrated. All levers are conveniently located and move easily since movements requiring appreciable effort to actuate are controlled by compressed air. The thrusting and retracting shovel, slewing to right or left, and opening shovel are all controlled from one universal lever. J.L.G.

Instrument for measuring the optical constants of small crystals. R. G. WOOD AND S. H. AYLIFFE. *Jour. Sci. Instruments*, **12** [6] 194–96 (1935).—A simple combination of a microscope-stage goniometer and cell for the immersion liquid is described and illustrated. With it crystals can be oriented under the microscope until the desired section is obtained as determined by noting the interference figure. Then the index of refraction can be determined directly by Becke-line observation. Thus, the three refractive indices of a biaxial mineral can be determined from one crystal. Conversely, the apparatus can be used to find the index of refraction of a liquid not in the range of the refractometer. In the latter determination, a biaxial-needle crystal with the intermediate axis, β, parallel to the length is rotated about the needle axis. This gives a continuous variation of index from α to γ. The index of the crystal is then a known function of the angle of rotation measured from the position in which the minimum axis, α, is parallel to the stage of the microscope. Measuring the angle at which a match is obtained with the liquid, therefore, determines the index of the liquid. Illustrated. J.L.G.

Lubricating molds for preparing refractory goods. T. IVANOVSKAYA. *Novosti Tekhniki, Seriya Gornorudnya Prom.*, No. 3, p. 12 (1935); *Chem. Abs.*, **29**, 4911 (1935).—Molds may be moistened with mixtures containing naphthenic acids. Suitable mixtures contain 5 to 20% "acid-oil," 60 to 95% kerosene, and up to 20% petroleum bottoms.

Practical knowledge with vacuum presses. A. C. HEIL. *Tonind.-Ztg.*, **59** [47–48] 569–71 (1935).—A review of literature on de-airing of clays is given and some practical results are discussed. M.V.C.

Reflection- and color-measuring instruments. RICHARD S. HUNTER. *Metal Cleaning & Finishing*, **7** [3] 113–16; [4] 189–92 (1935).—Color- and reflection-measuring instruments have been developed for measuring metallic finish and gloss or color and diffuse reflection. Gloss-measuring instruments measure intensity of specular reflection and can also be applied to metals. Satisfactory methods for measuring surface smoothness and lack of surface blemishes have yet to be developed. Instruments which measure diffuse reflection, color, and whiteness are of several types. Simple reflectometers measure the amount of light reflected. Spectrophotometers measure reflection intensities at all the wave-lengths of visible light. Color-filter reflectometers measure reflection intensities using different color regions of the spectrum. It is mainly in this particular field of color-measuring instruments that the photo-electric cell has been used to displace the human eye. Much work is necessary to adapt the color-sensitivity characteristics of the various photocells to colorimetric instruments. Illustrated. E.J.V.

Relation between coefficient of temperature conductivity and the moisture of material in the drying process. A. V. LIKOV. *Zhur. Tekh. Fiz.*, **5** [3] 467–82 (1935).—A mathematical and experimental treatment of the question is given. Turf, brick, clay, and coal were used for experimentation. See also "Temperature—" *Ceram. Abs.*, **14** [10] 254 (1935). S.I.P.

Small high-temperature hydrogen furnace. J. A. V. FAIRBROTHER. *Jour. Sci. Instruments*, **12** [6] 200–201 (1935).—The furnace consists of a tungsten or molybdenum heater wire wound on a fused quartz tube placed in a larger fused quartz tube. Hydrogen fills the space between the tubes and the inner tube. It burns at the open end of the furnace, which is mounted on a vacuum tube stem with the furnace leads going through the stem press while the hydrogen enters through the exhaust tube. The inner quartz tube is 10 by $^5/_8$ inch. Temperatures to 1400°C are attained with a quartz tube, but much higher ones are safely attained with an alumina tube for the furnace winding. Any desired temperature in the range can be reached in 2 or 3 min. Illustrated. J.L.G.

Steiner viscosimeter and its various applications. G. DEUTSCH. *Bull. Assn. Chim. Sucr.*, **51**, 383–89 (1934); *Brit. Chem. Abs.*, **54** [1] 1*B* (1935).—The Steiner viscosimeter is described, and some typical η-temperature curves for lubricating oils are discussed.

Surface examination in the foundry. G. STADE. *Giesserei*, **22** [14] 339–40 (1935).—A specially constructed microscope is described with which comparative surface examinations can be made of plane and curved surfaces as routine determinations in the shop. M.H.

Thin cell for determining the refractive indices of crystal grains. CHARLES PROFFER SAYLOR. *Jour. Research Nat. Bur. Stand.*, **15** [1] 97–98 (1935); R.P. No. 814. Price 5¢.—The use of those immersion methods for determining refractive index in which a regulation of temperature is employed has been seriously limited by the impossibility of obtaining interference figures. A thin cell which overcomes this obstacle is described, so that it is possible to know the exact orientation of the crystal grains which are chosen for identification. R.A.H.

Trouble shooting on waste-heat driers. ERNEST W. KNAPP. *Brick Clay Rec.*, **87** [2] 48–49 (1935).—While control of humidity and dry-bulb temperature helps in operating waste-heat driers, the control of the air circulation is the vital factor. This is almost a physical impossibility with a horizontal air movement. Remodelling a drier to render it controllable in all features and economical for waste heat should be done so it will not be out of line from a construction cost standpoint. Details of reconstruction of a 24-track waste-heat drier are presented. Illustrated. E.J.V.

Union calorimeter optimum volume of gas. W. C. Moss. *Jour. Sci. Instruments*, **12** [6] 188–91 (1935).—The results of experiments carried out to determine the gas volume required to give the calorific value within $\pm 0.5\%$ in the Union gas calorimeter are presented graphically. The optimum volume varies with the calorific value.

The range of 100 to 750 B.t.u./cu. ft. was investigated. The admixture of electrolytic gas with lean gas to assist combustion is unnecessary in the range tested. The Union calorimeter is described by Blackie, *ibid.*, **7**, 84 (1930).

J.L.G.

BOOK

Microscopes, Their Accessories and Application. L. G. TITOV. State Sci.-Tech. Pub. House of Machine Construction and Metal Treatment, Leningrad and Moscow, 1934. 408 pp. Price 7R 60k. Written by an engineer with more than 20 years experience in optico-mechanical establishments in the construction of compound optical apparatus, this book is an authoritative, practical contribution dealing with the construction of microscopes.

S. I. PERKAL

PATENTS

Drying plant for earthenware. PAUL THOR. Ger. 609,600, Feb. 19, 1935; *Chem. Abs.*, **29**, 5244 (1935). Addition to 534,619, Jan. 13, 1929.

Filtering apparatus and process of operating. RICHARD MENSING. U. S. 2,014,144, Sept. 10, 1935 (Sept. 20, 1932).

Grinding mill door. R. L. CAWOOD. U. S. 2,011,675, Aug. 20, 1935 (Oct. 13, 1933).

Induction electric furnaces. G. A. JUHLIN AND ASSOCIATED ELECTRICAL INDUSTRIES, LTD. Brit. 433,339, Aug. 28, 1935 (June 1, 1934).

Machines for making brick, etc. W. G. CHAPMAN AND DUNN'S ENGINEERING WORKS, LTD. Brit. 433,187, Aug. 21, 1935 (Feb. 20, 1935).

Kilns, Furnaces, Fuels, and Combustion

Burning characteristics of pulverized coals and the radiation from their flames. R. A. SHERMAN. *Trans. A.S.M.E.*, **56** [F.S.P.-6] 401 (1934).—A laboratory investigation of Hocking, Pocohontas, Illinois No. 6, and Pittsburgh No. 8 coals was made to determine the relation of the rate of burning and of flame radiation to the type of coal and to the fineness of pulverization. Principal conclusions drawn from results of this investigation are as follows: (1) fineness of grinding becomes increasingly important as combustion space is restricted; (2) the type of coal influences the combustion rate; (3) increased furnace temperature increases the combustion rate; (4) temperature and total flame radiation are affected by fineness of grinding; and (5) excess air, firing rate, and flame emissivity are affected only by the type of coal. See also "Effect—" *Ceram. Abs.*, **14** [10] 255 (1935). J.M.K.

Carbon and graphite electrodes. F. J. VOSBURGH. *Domes*, **7** [2] 96–97 (1935).—Historical data, methods of manufacture and graphitization, and uses of electrodes, the expenditure of electrode per ton of Al, calcium carbide, ferro alloys, nonferrous metals, steels, etc., are briefly discussed. S.I.P.

Carbonization of coal. Evaluation of effects of heating rate and of maximum temperature on pyrolysis of a coking coal. W. B. WARREN. *Ind. Eng. Chem.*, **27** [1] 72–77 (1935).—An apparatus for the pyrolysis of coal at controlled heating rates to fixed maximum temperatures is described. The effects of the two variables upon the yields and certain physical and chemical characteristics of all the classes of products of the pyrolysis of a typical coking coal at rates of 0.7, 1.4, 2.7, 5.5, 10.9, and 21.8°C/min. to maximum temperatures of 540, 700, and 1000°C are reported. With uniform heating rates throughout the ranges studied, the yields of tar increase with increase of heating rate at the expense of gas and coke; this increase is proportional to the ratio of the heating rate. It is concluded that the mechanism of coking involves competition between distillation and decomposition processes and that differences in the magnitude of their temperature coefficients are responsible for the increase in tar yield noted as the heating rate is increased. Solvent action of the liquid products of carbonization prior to distillation or decomposition may be an important factor in determining both the yields of the various products and their properties. Illustrated. F.G.H.

Changing aspect in the competitive market for industrial fuels. H. O. LOEBELL. *Amer. Gas Assn. Proc.*, p. 607 (1933).—A questionnaire to industrial men reveals that gas may command a premium over other fuels on a B.t.u. basis. Gas has a distinct advantage due to its cleanliness, its ease of control, and its automatic application in equipment designed and installed to develop these values. A discussion covers the following questions: (1) Is the trend in competing fuels going toward higher price levels? (2) Can the gas industry reduce its costs and rates?

J.M.K.

Combustion process in chamber-annular kilns. A. J. NACKEN. *Tonind.-Ztg.*, **59** [59] 701–703; [60] 716–17; [61] 728–29; [62] 742–44 (1935).—Changes in the composition of flue gases in a periodically fired chamber-annular kiln with overhead flame were determined. The changes in waste-gas composition empirically found are graphically represented. Flue gases of the last chamber are always used as air for combustion for the next, in the sense that oxygen has been partly replaced by CO_2 in these flue gases. During stoking, the false air sucked in does not markedly affect the mean composition of waste gases. The term "apparent surplus air figure" of the kiln is defined, and the figures of surplus air in the various chambers are determined. These researches show that during normal operation no products of incomplete combustion, which are formed because of lack of air, should be present in flue gases even with periodic operation.

M.V.C.

Combustion properties of industrial propane. W. Z. FRIEND. *Heat Treating & Forging*, **21** [6] 297; [7] 345; [8] 394 (1935).—Propane is obtained from natural gas in the production of natural gasoline and from refinery gases formed in the refining of oil. The commercial product from natural gas contains small amounts of ethane and butane, and the product from refinery sources contains, in addition, a percentage of propylene. The physical properties of pure propane and an industrial propane are given in tabular form. Charts and tables give the following physical and chemical properties: (1) products of combustion, (2) heat in the flue products,

(3) flue analyses, (4) flame temperatures, (5) rate of flame propagation, (6) limits of inflammability, (7) ignition temperature, (8) available heat, (9) specific heat of gaseous and liquid propane, (10) thermodynamic properties, and (11) vapor pressure and dew point. J.M.K.

Defects due to firing: their cause and elimination. A. HIELSCHER. *Tonind.-Ztg.*, **59** [27] 345–48; [28] 360–62; [29] 372–74 (1935).—A differentiation must be made between (1) defects which appear after firing but which are caused by faulty working or the poor quality of the clay (not firing defects but considered as such), and (2) defects due entirely to carelessness during firing or defects of the furnace. Both types and their cause are discussed in detail, and measures for their elimination are enumerated. M.V.C.

Effect of excess air on fuel rate. L. T. PEARSALL. *Heat Treating & Forging*, **21** [5] 247–49 (1935).—Excess air not only increases the sensible heat in the flue products but reduces the heating rate of the furnace because the rate of heat transfer to the work is dependent on the mean temperature difference between the gases and the ware being heated. Excess air introduced with the fuel lowers the average furnace temperature. An illustration is given for a furnace using natural gas, the heat losses being taken from a combustion chart designed for this purpose. J.M.K.

Electrically heated muffle furnaces. E. FÖLLINGER. *Elektrowärme*, **5** [8] 198–201 (1935).—Small types of furnaces for laboratory work, shop, and industry are described with particular regard to temperature control. M.H.

Firing brick with brown coal, coke, and flue dust. V. V. SAGALATOV. *Stroitel. Material.*, No. 3, pp. 29–31 (1935). P.B. & E.S.

Fundamental combustion reactions of natural gas. N. L. HOFF. *Western Gas*, **9** [6] 9 (1933).—The hydroxylization theory for the combustion of hydrocarbons is almost universally accepted. An initial reaction between the hydrocarbon molecule and the oxygen forms intermediate compounds such as formaldehyde and acetaldehyde. A warning of improper combustion conditions is given by the distinguishable odor of aldehyde vapors. J.M.K.

Gas consumption curves for brick firing. B. L. SWEET. *Western Gas*, **11** [4] 14 (1935).—The results from three kilns fired with natural gas were studied in order to recommend proper firing procedure. A temperature over-run due to an excessive firing rate is followed by considerable under-run when burners are turned down. Ideal firing rates are compared graphically with the actual rates used by skilled and unskilled firemen. J.M.K.

Gas utilization in the ceramic industry. H. C. WELLER. *Amer. Gas Assn. Monthly*, **17** [3] 120 (1935).—The present trend in the pottery industry is toward smaller, more compact units such as the circular-type continuous kiln. The next step will possibly be a smaller self-contained continuous kiln with one-third the production per unit of the present circular kilns. Attempts to fire clayware electrically have not been very successful, the exceptions being for firing decorated ware, enameled flat ware, glass leers, *i.e.*, in processes where static surface heating is adaptable and no uniform body firing is necessary. Clay bodies require uniform atmosphere and even kiln temperature. Work to be undertaken by the Ceramics Committee, Industrial Gas Section, American Gas Assn. includes (1) survey of existing kilns and furnaces, processes, methods of fuel utilization, equipment, unit costs, sales aspects, future trends, etc.; (2) interpretation and classification of survey work for the use of industrial gas engineers; (3) collaboration with the A.G.A. Comm. on Industrial Research, the American Ceramic Society, the Kilns and Fuels Comm. of the U. S. Potters Assn., and other agencies; (4) studies of fundamental requirements of each process where heat is used with emphasis on heating and cooling cycles, time and temperature contacts, effect of water-vapor, forced and induced draft, and volume and speed of heating gases. Since the ceramic industry expends from 20 to 30% of its total manufacturing costs for fuel, these subjects are always under consideration. J.M.K.

High-temperature flue-loss charts. AMERICAN GAS ASSN. TESTING LABORATORY. *Western Gas*, **10** [7] 15 (1934).—The accuracy and speed of making flue-loss calculations will be increased through use of the two charts shown. They are designed for use above 1000°F and for excess air varying from 0 to 10%. A parameter giving corrections for variation in heating value is provided. Values of flue loss for natural gas, varying in heat content from 1100 to 1180 B.t.u./cu. ft., and for coke ovens, varying from 520 to 600 B.t.u./cu. ft., may be obtained. J.M.K.

Improvement and reconstruction of a brick furnace. E. HÜTTEMANN. *Tonind.-Ztg.*, **59** [31] 391–92; [32] 404–405 (1935).—Furnace improvements which would increase output and improve the quality of products are discussed in detail. M.V.C.

Modernizing the oldest mechanical art. L. S. BRIGGS. *Amer. Gas Assn. Proc.*, 680 (1934).—The direct-fired research kiln developed and built at Lenox Pottery is defined as a straight, continuous, single-flow, open gas-fired, walking-beam kiln for glost operation. It replaces oil-fired, rectangular, muffle kilns. One of the objects of the research which led to the development of this kiln was to subject every piece of bisque ware to the same glazing conditions to produce uniformity in decorating operations. Open firing, in preference to standard muffle firing, was adopted to insure equal heat treatment. The results were as follows: (1) scumming of the ware was eliminated; (2) perfect glazing results were obtained on hollow ware; (3) even temperatures were maintained on top and bottom of the kiln; (4) loading solidly across the kiln increased ware production over 50% and decreased fuel consumption over 40%; and (5) additional changes were necessary for flat ware to eliminate pitting, blistering, and pock marking. J.M.K.

Radiation from luminous and nonluminous natural gas flames. R. A. SHERMAN. *Trans. A.S.M.E.*, **56** (I.S.-1) 177 (1934).—Conflicting statements in the technical press show that the difference between the two types of flames is not clearly understood. A discussion of the chemistry and physics of combustion and heat transfer of gas flames is presented with new data on large-scale laboratory experiments. The following conclusions as to transfer of heat are made: (1) Luminous gas flames obtained with slow-moving stratified streams of air and gas are inferior

to nonluminous flames from the viewpoint of efficient combustion. (2) With proper burner design, a more uniform temperature over the length of the furnace could probably be obtained with the luminous flame. (3) The total rate of heat transfer will be lower with a luminous flame in furnaces having walls hotter than the work being heated. Radiant heat transfer, flame temperature, and convection heat transfer are considered in arriving at this conclusion. (4) The advantage of the luminous flame lies in a more uniform transfer over the entire furnace as a result of slow combustion and slow heat liberation. (5) The presence of free carbon probably has a beneficial effect in the reduction of oxidation and scaling of steel. (6) Lack of data on the absorption of radiant heat by molten glass prevents a complete analysis of the heat-transfer phenomenon. J.M.K.

Standards for carbon electrodes. I. D. Nogaev. *Metallurg*, **10** [4] 103–105 (1935). S.I.P.

Temperature course in Dutch chamber furnaces for firing brick. P. Thor. *Tonind.-Ztg.*, **59** [40] 483–84 (1935).—Details of operation of Dutch chamber furnaces are given. M.V.C.

BULLETINS

Investigations of Fuels and Fuel Testing, 1932. *Can. Dept. Mines, Mines Branch Pub.*, No. 737, 155 pp. (1934).—Fifteen authors contribute to a general review and to nine reports of investigations. The studies made are (1) anthracite and coke analysis survey conducted at the Fuel Research Laboratories, (2) F.R.L. method for rating the grindability or pulverizability of coal, correlated with the Cross and Hardgrove methods, (3) a laboratory test on coals for predicting the physical properties of the resultant by-product cokes, (4) changes in forms of sulfur in coal under various conditions of weathering, (5) coal free from inorganic mineral matter for the purpose of classification, (6) batch experiments on the hydrogenation and cracking of low-temperature coal tar, (7) description of an apparatus for continuous hydrogenation experiments on coal tar, bitumen, and a suspension of powdered coal in coal tar, (8) a study of natural gas and naphtha products from twenty-four wells in Turner Valley, Alberta, and (9) gasoline survey for 1932. Nos. 1, 2, 3, 6, 7, and 8 have been published separately as advance sections of this report; No. 9 has been published separately as *Memorandum Series*, No. 60. G.M.H.

Petroleum Fuels in Canada. John M. Casey. *Can. Dept. Mines, Mines Branch Pub.*, No. 759, 12 pp. (1935). Price 10¢.—A statistical review of petroleum fuel deliveries for consumption in 1933 is presented. G.M.H.

PATENTS

Heat-treatment furnaces, kilns, stoves, etc. Birmingham Electric Furnaces, Ltd., and A. G. Lobley. Brit. 429,782, June 19, 1935 (Dec. 29, 1933).

Kiln trucks. B. J. Moore and C. Clifford. Brit. 433,497, Aug. 28, 1935 (July 14, 1934).

Muffle furnaces. Philip d'H. Dressler. Brit. 422,985, Jan. 23, 1935; *Chem. Abs.*, **29**, 4221 (1935).—In a muffle furnace in which a combustion space or recess at 1 or each side is bounded toward the muffle by a wall member which is free to expand upward, the wall member is mounted on a sand bed. A tunnel furnace is described.

Tunnel oven. B. J. Moore. Brit. 433,637, Aug. 28, 1935 (Feb. 19, 1934).

Geology

Alkaline earths and their uses. Charles Hardy and Paul M. Tyler. *Chem. Markets*, **32** [3] 227–30 (1933).—The discussion deals with calcium, strontium, and barium. Calcium is the only one of the three metals which has been used commercially on even a moderately extensive scale. Strontium has barely ceased being a laboratory curiosity and is not familiar to potential consumers. Barium has been available in commercial quantities or at anything less than a prohibitive price only since 1929. M.J.H.

Bauxite: ceramic raw material. V. C. *Verre & Silicates Ind.*, **6** [13] 244 (1935).—A brief discussion of the different grades of bauxite and their composition and the distinction between bauxite and clay (which formerly were not differentiated) are given. M.V.C.

British Columbia's industrial and nonmetallic minerals. A. M. Richmond. *Can. Mining Met. Bull.*, No. 280, pp. 373–88 (1935).—A statistical review is given. Building tile and some refractory clay products are made, but the principal product of the sixteen clay products manufacturers in the Province is common red brick. Deposits of higher grade clays are poorly located for immediate development. Large phosphate-rock deposits are not operated. Fluorspar is mined at Grand Forks. Bentonite, mined at Princeton, is used as bleaching clay. Kyanite has been found as float near Revelstoke. Magnesium sulfate is produced at Basque and sodium salts at Cherry Creek. Talc of lava type occurs in the western part of the Province. Other minerals occurring in the Province are barite, diatomite, magnesite, hydromagnesite, mica, pyrophyllite, mineral pigments, pumice, volcanic ash, and strontium minerals. Opportunities for development include glass manufacture, production of various clay products, and production of sodium sulfate. G.M.H.

Chrome. Anon. *Chem. Markets*, **28** [3] 268–70 (1931).—The history of the development and the mining of chrome ore in New Caledonia, a South Pacific island, is given. M.J.H.

Classification and properties of natural silicates from their structural formulas. R. Coquebert de Neuville. *Bull. soc. sci. natur. Ouest*, **2**, 91–171 (1932); *Rev. geol.*, **14**, 429; *Chem. Abs.*, **29**, 4702 (1935).—An attempt is made to write structural formulas of silicates and correlate their properties with no regard to modern X-ray work.

Classification of silicates. W. F. de Jong. *Natuurw. Tijdschr.*, **17**, 31–43 (1935); *Chem. Abs.*, **29**, 4701 (1935).—By means of an extensive table the best known of the silicates are classified into groups according to the following outline: (I) (in which the Si is not replaceable by Al) (*a*1) [SiO_4], (*a*2) [Si_2O_7], (*a*3) [Si_3O_{10}], (*a*4) both [SiO_4] and [Si_2O_7], (*b*1) [Si_3O_9] (ring containing 3 Si), (*b*2) [Si_6O_{18}] (ring of 6 Si); (II) (in which $^1/_4$ of the Si is

replaceable by Al) (*a*1) [SiO_3], (*b*1) [Si_2O_5] (rings of 4 Si), (*b*2) [Si_4O_{11}] (rings of 6 Si); (III) (in which $^1/_4$ to $^1/_2$ of the Si is replaceable by Al) (*a*1) [Si_3O_7] (rings of 4 Si and 6 Si), (*a*2) [Si_8O_{20}] (rings of 4 Si and 8 Si), (*a*3) [Si_4O_{10}] (rings of 6 Si); (IV) (in which $^1/_2$ of the Si is replaceable by Al) [Si_mO_{2m}]. Structural formulas are given for the complex configurations. References are given to each of the minerals classified.

Clay constituents. C. CORRENS. *Z. deut. geol. Ges.*, **85** [9] 706–12 (1934); abstracted in *Referathartei Silikatliteratur*, No. 402 (1934).—The mineral constituents of clay are discussed in detail. M.V.C.

Correlation between specific gravity, chemical constitution, and condition of formation of minerals and rocks. D. C. NAG. *Quart. Jour. Geol. Mining Met. Soc. India*, **4**, 29–67 (1932); *Chem. Abs.*, **29**, 4705 (1935).—In an attempt to determine the condition of formation of solid compounds, their specific gravities are calculated from the chemical analyses with the help of "fundamental factors" on the assumption that the molecular volume of a compound is equal to the sum of the volumes of its constituents. The "calculated specific gravity" is only a hypothetical value corresponding to standard conditions.

Determining the ability of clays to absorb water. F. F. LAPTEV AND V. S. SHAROV. *Neftyanoe Khozyaistvo*, **26** [11] 19–22 (1934); *Chem. Abs.*, **29**, 4535 (1935).—The test adopted by the Standards Committee of the American Ceramic Society is modified in that the samples, prepared from a clay of normal consistency, are placed in desiccators over solutions of H_2SO_4 of various concentrations, *viz.*, 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5, 25, 30, 35, and 40%. A definite water-vapor tension is established in the desiccators, depending upon the concentration of H_2SO_4. The samples are kept in the desiccators until constant weight is reached (1.5 to 2 months, 3 samples in each desiccator). One sample is then dried in the air and in a drying chest at 110° and weighed for the H_2O determination. The remaining two samples are investigated in the usual manner for their ability to absorb water. Illustrated.

Developments in 1934 in Ontario raw materials for the ceramic industry. W. S. DYER AND W. R. ROGERS. *Jour. Can. Ceram. Soc.*, **4**, 59–60 (1935).—Refractory clays: Large quantities of fire clay and sedimentary china clay exist in the Moose River basin in northern Ontario, but this clay is so located that it will prove difficult to recover. Deposits near the railway, like the gray and black fire clays of the Onakawana lignite field, are covered under 50 to 100 feet of glacial débris and would have to be mined by underground methods. Deposits under shallow overburden, like the beautiful highly refractory white and mottled clays of the Missinaibi River, are 30 miles across the muskeg from a railway. The Hilder deposit is now being investigated by Minefinders, Ltd. This deposit is on the west side of the Mattagami River 7 miles north of Smoky Falls, the terminus of a 50-mile logging railway from Kapuskasing. The work has indicated that in an area of a few acres a good body of clay rises above the water level of the Mattagami River and is overlain by overburden of only 35 ft. In 1934 Minefinders, Ltd., built a road into the property, erected camps, took in a shovel with $1^1/_2$ cu. yd. capacity, and completed an open cut 350 by 150 ft. In the bottom of the open cut, which is 25 to 30 ft. deep, cretaceous refractory clay and silica sand are exposed. Nepheline syenite: The Nepheline Company, Ltd., was incorporated in Aug., 1934, to develop a deposit of nepheline syenite in Methuen township, Peterborough county, near the east end of Stony Lake. This rock has a chemical composition which makes it suitable for use in the glass industry. The combined alkalis, soda, and potash run about 15%. Low silica and high alumina content give this rock a low fusion or fluxing point, lower than feldspar which is now used in the pottery trade. Markets are being canvassed and tests appear satisfactory. It is proposed to quarry the rock crush to 20-mesh and ship by barge to Lakefield and thence by rail. Other deposits of nepheline syenite occur in eastern Ontario, but some are impure or have not the correct chemical composition or are remote from transportation. J.G.P.

Dickite from Pennsylvania. ARTHUR P. HONESS AND FRANCIS J. WILLIAMS. *Amer. Mineralogist*, **20** [6] 462–66 (1935).—Two new localities for the rather rare mineral, dickite, are given, together with a summary of the optical, chemical, and X-ray data on this material. F.J.Z.

Dispersion of the calcium-sodium feldspars. E. LEISEN. *Z. Krist.*, **89**, 49–79 (1934); *Chem. Abs.*, **29**, 4701 (1935).—The dispersion of the several optical directions is shown both numerically and graphically.

Distribution of heavy minerals in clays of Middlesex County, New Jersey. ALFRED C. HAWKINS. *Amer. Mineralogist*, **20** [5] 334–53 (1935).—Cretaceous clay samples selected from various stratigraphic horizons in Middlesex County were elutriated, and residues were examined petrographically. Most of the samples were obtained from east-central N. J. Various minerals other than kaolin and quartz, including zircon, ilmenite, and tourmaline, were determined as well as the organic carbon content. Relationships between these are plotted stratigraphically and areally to make possible the correlation of clay beds whose exact relationships were hitherto unknown. The distinct fan-like distribution of these beds of clays indicates an origin in the northwest part of N.J. and the action of a river of considerable size and drainage area. F.J.Z.

Geology and clay research. H. RIES. *Bull. Amer. Ceram. Soc.*, **14** [9] 279–90 (1935).

Hydrological research in chalk of the Paris basin. C. P. NICOLESCO. *Compt. rend.*, **201** [3] 224–26 (1935).—Stratification and geological conditions in the chalk regions of Paris and Haute Normandie are described, and the tectonic movements which have taken place are discussed. M.H.

Hydrothermal synthesis of kaolinite, dickite, beidellite, and nontronite. RAYMOND H. EWELL AND HERBERT INSLEY. *Jour. Research Nat. Bur. Stand.*, **15** [2] 173–86 (1935); R.P. 819. Price 5¢.—Kaolinite was synthesized by heating coprecipitated Al_2O_3·SiO_2 gels and mixtures of Al_2O_3 and SiO_2 with water in a pressure bomb at 310°C. Similarly, dickite was prepared by treating coprecipitated Al_2O_3·SiO_2 gels at 350 and 365°C, and beidellite from mixtures of Al_2O_3 and SiO_2 at 350 and 390°C and also from coprecipitated gels and kaolinite at 390°C. Beidellite was formed in these experiments in the presence of soda by transport of SiO_2 in solution to the Al_2O_3 and reaction with Al_2O_3, *in situ*. The products were identified

by X-ray patterns. Their optical properties were also consistent with those of the natural minerals. The stability ranges of kaolinite, dickite, and beidellite probably occur in the order named, with increasing temperature. This relation between kaolinite and dickite is consistent with geological evidence as to their formation in nature. R.A.H.

Italian chemical industry. Barium salts. MASSIMO TREVES. *Chem. Markets*, **28** [2] 142 (1931).—A plant near Milan mines barytine (natural barium sulfate) and produces chemically pure barium sulfate. Blue mineral of Sicily is also worked for the preparation of strontium salts, and sodium sulfate is produced for the preparation of anhydrous sodium phosphate. M.J.H.

Metallic cousins with a chemical future. S. SKOWRONSKI AND M. A. MOSHER. *Chem. Markets*, **30** [5] 441 (1932).—Selenium is of commercial importance in the glass industry, where it is employed as a decolorizer and in the manufacture of ruby glass. The ceramic industry uses selenium in conjunction with cadmium sulfide to obtain various red and orange shades of enamel. The commercial uses of tellurium, which remain small, are discussed. M.J.H.

Most common American mineral. ANON. *Chem. Markets*, **28** [1] 34–37 (1931).—The feldspar industry has been handicapped for many years by the lack of (1) intelligent operation and (2) standardization of grades, but these handicaps are being overcome. Little information is readily available as to consumption and widening industrial possibilities. Uses are given and suggestions are made for other possible uses. The greatest need for the future is to find some use for which huge tonnages of feldspar will be required so that mills will be able to operate at full capacity and thus reduce costs. M.J.H.

Plastic clays of Andenne: their origin and exploitation. H. J. *Verre & Silicates Ind.*, **6** [13] 238–42 (1935).—The plastic clay mine at Andenne, which has been worked for 15 centuries, is described. A classification of the grades of clay (a double silicate of alumina (13 to 40%) hydrated and impure) and the method of mine operation are given. M.V.C.

Sardinian kaolin as important national material. F. DE CARLI. *Chimica & Industria*, **17** [6] 399–405 (1935).—The extensive deposits of kaolin on the isle of Sardinia are described, and geographical and geological conditions are discussed. The average composition is SiO_2 59.46, Al_2O_3 27.0, Fe_2O_3 2.31, CaO 0.25, and $Na_2O + K_2O$ 0.10%; loss at 120°C 0.7%, at 900° 9.72%. M.H.

Sericite of unusual composition. DOROTHY BABCOCK MEYER. *Amer. Mineralogist*, **20** [5] 384–88 (1935).—A peculiar mineral, ranging in hardness from 1 to 4 and occurring on Pilot Knob, Mo., has been erroneously called steatite, serpentine, and talcose clay in various publications. It is a sericite with an abnormally high soda content. X-ray patterns checked the results of analytical work. A dehydration curve for this material is shown. F.J.Z.

Spectrographic examination of smoky and ordinary quartz from Rincon, Calif. T. G. KENNARD. *Amer. Mineralogist*, **20** [5] 392–99 (1935).—The colorless and the very pale smoky quartz were found to contain more lithium than the dark smoky quartz, regardless of whether or not the various colored types formed parts of the same crystal; no other significant difference in composition, as to metallic constituents, was found. An improved spectrographic technique for examining minerals is described. F.J.Z.

Stages of metamorphism of the emeries of Samos. J. DE LAPPARENT. *Compt. rend.*, **201** [2] 154–57 (1935).—This emery had its origin in ancient bauxites. The course of transformation through different stages is described, and the geological conditions under which they took place are discussed. M.H.

Structures of halloysite and metahalloysite. M. MEHMEL. *Z. Krist.*, **90**, 35–43 (1935); *Chem. Abs.*, **29**, 4699 (1935).—Although very similar to kaolinite, metahalloysite is distinct from it. The space group is C_s^3 instead of C_s^4 (for kaolinite). Single sheets of the structure are similar to those of kaolinite. The lattice constants are $a = 5.15$, $b = 8.9$, $c = 7.57$Å, $\beta = 100°$, $Z = 2$. For halloysite, the dimensions are $a = 5.20$, $b = 8.92$, $c = 10.25$Å, $\beta = 100°$. On the basis of optical data, halloysite does not alter to kaolinite.

Unique raw material. J. N. WILSON. *Chem. Trade Jour.*, **95** [2470] 202 (1934).—Bentonite has a particle size of from one to 500 mμ, whereas the particle size of good china clay is about 1μ. Mixed with 25 parts of water, 90% of the bentonite stays in suspension. Bentonite absorbs 5 to 6 times its weight of water, and swells to 14 to 16 times its dry bulk. The chemical analysis shows 64.6 silica, 21.3 alumina, 3.2 ferric oxide, 0.3 ferrous oxide, 0.7 lime, 2.7 magnesia, 0.3 potash, 2.3 soda, and 4.7% chemically bound water. The fusion temperature is 1340°C. It is used for foundry molds, an admixture to the clean sand resulting in better bonding and in greater permeability for gases. Better and sharper casts can be obtained with bentonite, and the chances for failure are greatly reduced. H.K.

Viscosity of the sol of Yamagata water-imbibing clay, a species of bentonite. MUNE UTIDA. *Jour. Jap. Ceram. Assn.*, **43** [507] 121–32 (1935).—The viscosity of the sol of Yamagata water-imbibing clay has been measured by capillary and falling-body methods with the following results: (1) Dense sol of the clay shows some anomalous viscosities. Structural viscosity of the sol is an indication of any gel structure. The structure is easily broken with a small shearing stress exerted by the flow head of the capillary, causing serious apparent viscosity drop. Yet the broken structure of the sol has a self-curing ability. With the falling-body method, the apparent viscosity of the sol increases gradually with increasing path of the falling body. (2) With the thinner sol, the following relation exists between the relative viscosity, η_r, and its concentration, C, in grams per 100 cc.: $\log \eta_r = \alpha C + \beta C^2$, where α and β are constants. (3) When the sol is thin, the effect of temperature is the same as that given by Poiseuille for pure water: $\eta_t = \eta_0/(1 + pt + qt^2)$, where η_t and η_0 are viscosities at $t°$ and 0°, respectively, p and q being constants. (4) The specific hydrodynamical value, ϕ, of the clay in the sol is calculated with the following formula presented recently by Ichiro Sakurada for cellulose sol: $\eta_r = \eta_s/\eta_0 = 1 + a\phi c/(100 - \phi c)$, where η_s and η_0 are the viscosity coefficients of the sol and medium, respectively, η_r is the relative viscosity, c the concentration

in grams per 100 cc., and a a constant. The average value of ϕ for the clay is 32.5 cc. per 100 cc. of sol containing 1 g. of dry mass at 10 to 35°C. The value decreases slightly with increasing temperature. (5) The particle suspending in dilute sol must be a fragment of the gel structure. It seems to undergo some visco-elastic but not plastic deformation by any stress and to be a complex grouping of some flexible chain-like aluminosilicic molecules. Every heavy molecule or unit micella must have dense and less-mobile liquid layer or ionic swarm on and near the surface. S.K.

Witherite as a chemical raw material. H. Conrad Meyer. *Chem. Markets*, **32** [4] 317–19 (1933).—Witherite (natural barium carbonate) is a relatively rare mineral. Its sources, history, properties, and uses are given. The normal commercial demands for natural barium carbonate are, in order of their importance, case-hardening, sugar refining, heavy clay products, barium peroxide, water and brine purification, barium chemicals, glass, and enameled iron ware. A discussion of some of these uses is given. M.J.H.

X-ray studies of Danish clays. Hans Clausen. *Medd. Dansk Geol. Foren.*, **8** [2] 7 pp. (1932); *Rev. geol.*, **15**, 5; *Chem. Abs.*, **29**, 4701 (1935).—Patterns were made of the Danish Mesozoic and tertiary clays. Those of kaolin from different localities were identical but different from those of the clays.

Zirconia and its industrial applications. W. O. R. Wynn. *Refrac. Jour.*, **10** [9] 377 (1934).—The occurrence and methods of concentrating zirconia are discussed. Zirconia has a density of 5.45 to 5.89, a melting point of 2560 to 2950°C, a coefficient of expansion near that of silica, about 0.00000084. The thermal and electrical conductivities are also low. Zirconia is used in making high-grade refractories, such as special refractories, crucibles, muffles, combustion tubes, pyrometer tubes, etc. It is also used as an opacifier for sheet-steel and cast-iron enamels, a beneficial ingredient in special porcelains, such as spark plug porcelains, a substitute for silica in special glass batches, and for a few other dispersed uses, such as abrasives and paint fillers. M.C.S.

BOOKS AND BULLETINS

Canadian Mineral Industry in 1934. *Can. Dept. Mines, Mines Branch Pub.*, No. 760, 119 pp. (1935).—Twelve authors, under fifty-four headings, review the current situation in respect to important Canadian minerals. G. M. Hutt

Getting Acquainted with Minera's. G. L. English. 324 pp., 258 figs. Mineralogical Pub. Co., Rochester, N. Y., 1934. Price $2.50. Briefly reviewed in *Econ. Geol.*, **30** [4] 459 (1935).—This is an interesting introduction to mineralogy. Optics are not considered. J.L.G.

Investigations in Ore Dressing and Metallurgy, 1932. *Can. Dept. Mines, Mines Branch Pub.*, No. 736, 287 pp. (1934).—Twelve authors contribute to reports on metallic ores, hydrometallurgy and electrochemistry, ferrous metallurgy, chemistry, and, of interest to ceramists, nonmetallic ores. Reports on investigations of nonmetallic minerals include (1) concentration of garnet from River Valley, Ontario; (2) treatment of diatomite from Martin Siding, Ontario; (3) separation of gypsum and dolomite from Amaranth, Manitoba; (4) testing of a quartz from Larouche, Quebec, which is too dirty for use as potter's flint, fair as blast sand, and suitable for use in paint; (5) method of separation of dolomite from talc from Madoc, Ontario; (6) tests on barite from Strathlorne, Nova Scotia; (7) concentration of kyanite found only as float at Death Rapids, near Revelstoke, British Columbia; (8) preparation of commercial products from a mixture of quartz and china clay at St. Remi, Quebec; and (9) tests on anhydrite from Baddeck Bay and on gypsum from Windsor, Nova Scotia. **July to December, 1933.** *Ibid.*, No. 744, 194 pp. (1934).—This report covers investigations on forty minerals and ores. These include concentrating tests on two Quebec garnet rocks and on barite from Ontario, tests on a low-grade diatomite from Burnaby Lake, British Columbia, a study of health hazards in handling radium, and the cleaning of broken glass. G. M. Hutt

Mineral Industries of Canada. A. H. A. Robinson (compiler). *Can. Dept. Mines., Mines Branch Pub.*, No. 738, 116 pp. (1934). 34 plates, mineral map of Canada.—R. discusses the situation in Canada of sixty-two minerals and reviews the mineral production by provinces. G. M. Hutt

Petrographical Dictionary. F. Yu. Levinson-Lessing. Central Sci.-Research Geological Prospecting Institute. State Sci. Tech. Geol. Prospecting Pub. House, Leningrad and Moscow, 1932. 472 pp. Price 15R. S. I. Perkal

Strontium deposits of southeastern California and western Arizona. B. N. Moore. *Amer. Inst. Mining Met. Eng. Tech. Pub.*, No. 599, 24 pp. (1935).—Strontium is imported from Germany, England, and Canada. Domestic deposits of strontium ores in the desert region below Boulder Dam have been investigated by the U. S. Geological Survey. Five known deposits of celestite contain large amounts of high grade, easily accessible material. Much of the ore contains 70 to 90% of strontium sulfate. A.P.

Surface Deposits and Ground-Water Supply of Winnipeg Map-Area, Manitoba. W. A. Johnston. *Geol. Surs. Can.*, Memoir No. 174, Pub. No. 2363, 110 pp. (1934). 12 tables, 3 figs., map in folder. Price 25¢. Most of the clays that have been used in the brick industry are either formed from the overflow of streams or are ancient delta deposits. The lake clays are too highly plastic for brick-making. Most of the clays are high in lime. G.M.H.

PATENT

Treatment of clays. English Clays, Lovering, Pochin, & Co., Ltd., and R. J. Davies. Brit. 433,416, Aug. 28, 1935 (Dec. 24, 1934).

Chemistry and Physics

Band spectrum of arsenic oxide (AsO). F. C. Connelly. *Proc. Phys. Soc.* [London], **46**, 790–800 (1934).—The spectrum of arsenic oxide has been photographed. Illustrated. L.E.T.

$CaO \cdot TiO_2 \cdot SiO_2$–$CaO \cdot SiO_2$–$CaO \cdot Al_2O_3 \cdot 2SiO_2$ system. I. Equilibrium diagram of the system $CaO \cdot SiO_2$–$CaO \cdot Al_2O_3 \cdot 2SiO_2$. Usaburo Nishioka. *Kinzokuno-Kenkyu*, **12**, 168–71 (1935); *Chem. Abs.*, **29**, 5003 (1935).—Samples quenched

at various temperatures were studied microscopically. The equilibrium diagram of the binary system, $CaO{\cdot}SiO_2$–$CaO{\cdot}Al_2O_3{\cdot}2SiO_2$, was constructed. In this system, eutectiferous mixtures were formed, the eutectic point being 1283°, 57% (by weight) $CaO{\cdot}SiO_2$.

Change of inner structure of quartz and feldspar heated at high temperature. T. NAKAI AND Y. FUKAMI. *Jour. Soc. Chem. Ind.* [Japan], **38** [7] 340–42*B* (1935).—The changes that occur in quartz and other siliceous materials and feldspars heated at high temperatures are given in detail. See *Ceram. Abs.*, **13** [11] 294 (1934). M.V.C.

Chemical and physical studies of synthetic spinels colored with cobalt. HANS-WERNER TROMNAU. *Neues Jahrb. Mineral. Geol., Beil.-Bd.*, **68A**, 349–76 (1934); *Chem. Abs.*, **29**, 5003 (1935).—In preparing synthetic spinels, the Co content of the crystals is lower than that of the total composition of the mixture, the Mg content is lower, and the Al_2O_3 content is considerably higher. Spinels with low Co content, on heating at 850°, show corundum crystals, while with higher Co content no corundum appears. The spinels are an isomorphous mixture of $MgO{\cdot}xAl_2O_3$ and $CoAl_2O_4$. Data on specific gravity, hardness, and optical properties are included.

Color reaction for calcium, strontium, and barium. G. AMMER AND H. SCHMITZ. *Wasser*, **8** [Part II], 161–68 (1934); *Chem. Abs.*, **29**, 4285 (1935).—When tannic acid is added to dilute slightly alkaline solutions of Ca, Sr, or Ba salts, or mixtures of these, a yellow-green color is developed which rapidly changes to a blue and after 3 to 5 min. fades to a yellow again. In concentrations of less than 0.1 mg./liter (or the metal) only the yellow color develops, and in solutions more concentrated than 100 mg./liter a blue-green precipitate forms, making dilution of the sample necessary. A preliminary report of a quantitative procedure is given. Because of the rapid fading of color, comparisons must be made rapidly. Ten cubic centimeters of the neutralized sample are placed in the middle one of 3 Nessler-type tubes, the outer 2 tubes containing solutions of Ca, Sr, or Ba of known concentrations. Two drops of 2 *N* NaOH and 1 drop of 10% tannic acid are added to each tube; all are shaken, and the colors are compared at once. Repetition with varying concentrations in the controls is necessary until matching colors are obtained. Heavier metals interfere only when present in sufficiently high concentrations to be precipitated by NaOH. Mg in concentrations greater than 5 to 10 mg./liter or greater than 30% of the Ca, Sr, and Ba in very dilute solutions interferes, retarding color development in the very dilute solutions and producing a white precipitate in the more concentrated solutions. The method does not differentiate Ca, Sr, and Ba and can be used for the determination of Ca in cases (as most waters) where Sr and Ba are absent.

Development of the diagram FeO-SiO_2. D. P. BOGATSKIĬ. *Metallurg*, **10** [5] 89–95 (1935). S.I.P.

Infra-red arc spectrum of chromium. C. C. KIESS. *Jour. Research Nat. Bur. Stand.*, **15** [1] 79–86 (1935); R.P. 812. Price 5¢.—The new type of plates, sensitive to infra-red light, have made it possible to photograph the arc spectrum of chromium out to 11,610Å. Approximately 200 wave-lengths have been recorded for this region. R.A.H.

Kinetics of the thermal dissociation of magnesite and resultant intermediate chemical combinations. G. F. HÜTTIG, WOLFGANG NESTLER, AND OTTO HNEVKOVSKY. *Ber. deut. chem. Ges.*, **67**, 1378–87 (1934).—The thermal decomposition of a solid body, *e.g.*, $MgO + CO_2$ at various temperatures, such as 490, 510, and 530°C has been studied by the aid of X-ray, and the results are tabulated and shown on diagrams. L.E.T.

Law of phases and diagrams of equilibriums in the study of industrial silicates. LEON FRANCQ. *Verre & Silicates Ind.*, **6** [14] 253–57 (1935).—The 3-constituent systems are taken up here. In a ternary system there are four independent variables: pressure, temperature, and two variables of composition. Different ways of representing the variables of composition geometrically are shown. Types of ternary equilibriums are reviewed. See *Ceram. Abs.*, **14** [8] 200 (1935). M.V.C.

Manufacture of aluminium oxide from urtite by the sulfurous acid method. T. YA. TARDSSOV AND N. A. KHMELEVSKAYA. *Zhur. Prik. Khim.*, **7** [4] 529–34 (1934). S.I.P.

Measurement of the electrical constants of soils. R. L. SMITH-ROSE AND J. S. MCPETRIE. *Proc. Phys. Soc.* [London], **46**, 649–58 (1934).—The electrical properties of soil were determined with alternating current of a frequency corresponding to a wave-length of 1.5 m. A parallel Lecher-wire system was used to determine the electrical conductivity and dielectric constant of the soil. The former was found to be 10 to 28×10^8 e.s.u. and the latter showed a value of 10 to 12 at normal moisture content. L.E.T.

Photographic determination of the intensities of X-ray reflections from powders. G. W. BRINDLEY AND F. W. SPIERS. *Proc. Phys. Soc.* [London], **46**, 841–52 (1934).—A simple and accurate method of measuring the intensities of X-ray reflections from powders is described. L.E.T.

Potentiometric studies on the precipitation of hydroxides. ERICH HAYEK. *Monatsh.*, **65**, 233–38 (1935); *Chem. Abs.*, **29**, 4289 (1935).—The determination of Pb in the presence of Cd, Zn, Mg, Ca, and Ba is described. For this determination, suitable amounts of KCNS and KCl are added, the solution is titrated with NaOH, and the precipitation of the basic salt, $Pb(OH)_2{\cdot}Pb(CNS)_2$, is followed to a potentiometric end point with an Sb or an O_2 electrode.

Preparation and properties of titanium pigments. Properties of titanium sulfate solution. L. T. WORK, S. B. TUWINER, AND A. J. GLOSTER. *Ind. Eng. Chem.*, **26** [12] 1263–66 (1934).—The attainment of pigment value in a calcined titanium oxide is affected by many factors, beginning with the character of the solution. In the system titanium oxide–sulfur trioxide–water, certain zones tend to produce more suitable precipitates, and an analysis of the solution from the partial volume viewpoint has shown that dilute solutions are hydrolyzed appreciably and that such hydrolysis is materially affected by the acid content. After the precipitation is complete, the residual concentration may play an important part in the state of the precipitate. A brief mathematical treatment reveals that this end condition may be used as one criterion of the character of the titanium pigment which will result. **Effect of precipitation, calcination, and subsequent treat-**

ment. L. T. WORK AND S. B. TUWINER. *Ibid.*, pp. 1266–68.—Calcination tests reveal marked differences in the character of the precipitate. The recognized effect of seeding is of dominant importance. Pigments produced from unseeded solutions tend to be coarse in size when distribution curves are shown. The effect of the calcining temperature is of limited importance over a normal range but varies appreciably at temperatures above 850°C. The character of the pigment appears to be agglomerate rather than crystalline, and milling produces significant effects in oil absorption and hiding power. Microscopic examination of milled particles shows the structure of individual particles and clusters. The counting of doublets, triplets, etc., is used as a criterion of this effect. Illustrated. F.G.H.

Reactions in the solid state at high temperatures. IX. Dependence of reaction velocity upon type of preparation, impurities, and relative proportions of the reacting substances. WILHELM JANDER AND ERNA HOFFMANN. *Z. anorg. allgem. Chem.*, **202**, 135–53 (1931); *Chem. Abs.*, **26**, 1502 (1932).—$BaCO_3$ + SiO_2 and $CaCO_3$ + MoO_3 were studied in the vicinity of 1000° and 500°, respectively, by determining the temperature coefficient under varying conditions. A change in conditions of preparation had no effect on the work of decomposition but did influence the number of diffusion centers, as did also foreign substances such as TiO_2, NaCl, CaF, and WO_3. Variation in the relative proportions of reacting substances has no influence on the work of decomposition if only one compound is formed in the reaction, but if more compounds are formed, it has an influence. **X. Course of the reaction.** WILHELM JANDER AND WALTER SCHEELE. *Z. anorg. allgem. Chem.*, **214**, 55–64 (1933); *Chem. Abs.*, **27**, 5621 (1933).—The reactions in mixtures of $BaCO_3$ + MoO_3, $BaCO_3$ + WO_3, ZnO + Cr_2O_3, and ZnO + Al_2O_3 were studied, and a theory of the course of the reaction is advanced. According to this, an amorphous or pseudomorphous reaction zone is first formed at the contact surface of the reaction partners, from which the crystalline reaction product is then formed. Optical evidence of the reaction zone is furnished by means of a polarization microscope. See *Ceram. Abs.*, **9** [11] 981 (1930); **11** [1] 62 (1932).

Refractometer and other refractive-index methods. B. W. ANDERSON. *Gemmologist* [London], **3**, 216–22 (1934); *Mineralog. Abs.*, **5**, 503; *Chem. Abs.*, **29**, 4981 (1935).—Tetra-iodoethylene and S dissolved in CH_2I_2 give a clear, stable liquid with n_D = 1.81. Phenyldiiodoarsine is a clear orange liquid with n_D = 1.843. Se monobromide has n_{Li} = 1.96, rising to 2.02 on decomposition. The use of a hemisphere of zinc blende (n_D = 2.37) is suggested for measuring liquids.

Researches on the properties of mono-, di-, and tricalcium silicates and on mono-, pentatri-, and tri-calcium aluminates. P. SCHLÄPFER AND G. BERGER. Eidgen. Material-prüfungsanst., Zürich, Report No. 67; abstracted in *Referatkartei Silikatliteratur*, No. 237 (1934). M.V.C.

System calcium nitrate–water. J. BUREAU. *Compt. rend.*, **201** [1] 67–69 (1935).—The thermal analysis proved the existence of the hydrates $(NO_3)_2Ca{\cdot}4H_2O$ and $(NO_3)_2Ca{\cdot}1H_2O$. Transformation and solidification points were determined. M.H.

Theory of refraction of a prism outside of the principal section. M. SCULC. *Acta phys. Polon.*, **3**, 115–21 (1934); abstracted in *Physik. Ber.*, **16** [13] 1135–36 (1935).—A theory for calculating the refractive index of a prism for a ray passing through it outside the principal section is developed, and its application is illustrated by examples of special cases. M.H.

Thermal and electrical conductivities of metals and alloys. I. Iron from 0 to 800°C. R. W. POWELL. *Proc. Phys. Soc.* [London], **46**, 659–79 (1934).—A longitudinal flow method has been used to determine the thermal conductivity of a nickel-plated rod of Armco iron (approximately 99.92% iron). The conductivity decreases with increase in temperature, the values being 0.177 c.g.s. units at 0°C and 0.071 c.g.s. units at 800°C. Illustrations of apparatus, diagrams, and data are given. L.E.T.

Use of 8-hydroxyquinoline in determinations of aluminum, beryllium, and magnesium. HOWARD B. KNOWLES. *Jour. Research Nat. Bur. Stand.*, **15** [1] 87–96 (1935); R.P. 814. Price 5¢.—The methods commonly used for precipitating aluminum by 8-hydroxyquinoline from an acetic acid solution, buffered with ammonium acetate, do not sufficiently define the conditions requisite for complete precipitation. K. describes a method in which aluminum is precipitated as the oxyquinolate from a solution which has been partly neutralized with ammonium hydroxide, using bromcresol purple as an indicator. Results obtained in the separation of aluminum from beryllium and magnesium, and in the separation of beryllium in the presence of aluminum, iron, titanium, and zirconium by the described procedure are given. R.A.H.

Utilization of cement dust. III. SEIJI KONDO AND CHIHIRO KAWASHIMA. *Jour. Jap. Ceram. Assn.*, **43** [507] 142–53 (1935).—A study was made of the chemical changes in Cottrell cement dust when stored indoors and outdoors, the P.C.E. of the system silica–dust and the system feldspar–dust, and the devitrification of silica-soda-dust glasses. The field producing faultless glass in the last system was determined more precisely than in the preceding report. Conclusions are as follows: (1) The slight but abrupt loss in weight shown in the heating curves of the weathered dusts at about 250°C is caused probably by the decomposition of $3MgCO_3{\cdot}Mg(OH)_2{\cdot}3H_2O$. (2) Each P.C.E. curve of the system silica–dust and the system feldspar–dust has a maximum and two minima. Wollastonite is probably formed mainly at the maxima. (3) The utilization of the dust is 50% or less when quartz is used. (4) Well-developed crystals in the devitrified glasses are fibrous and each fiber is surrounded by a black glass which reduces the n_D of the crystal mass. The n_D are very near to those of $RO{\cdot}3CaO{\cdot}6SiO_2$. The X-ray patterns of the crystals coincide precisely with those of wollastonite. **IV.** *Ibid.*, **43** [508] 208–14 (1935).—Many batches in the systems silica–feldspar–dust, silica–soda–feldspar–dust, and Hodogaya sand–soda–dust were fired to 1410°C to find the fields of satisfactory glass with results as follows: (1) Members of the first system were too refractory and the utilization of the Cottrell cement dust was only 20 to 30%. (2) The glasses made of quartz sand, soda ash, feldspar, and the dust were not devitrified. The field of faultless glass was pretty wide, and the utilization of the dust amounted to 50% in the

system. (3) Many batches in the last system gave faultless glasses, but the utilization of the dust was only 25%. (4) Satisfactory glasses can be made of the dust, soda ash, and sand. The sand may be pure or impure. The sand of Hodogaya has long been used in the manufacture of beer bottles. It is a tuff, analyzing as follows: silica 70.74, alumina 12.27, ferric oxide 2.94, lime 1.69, magnesia 0.72, potash 4.00, soda 3.81, and loss on ignition 4.04%. Since the dust contains 2.5% of ferric oxide, it can not be used for colorless glass. S.K.

Validity of Antonow's rule for the solid-liquid interface, and the consequent measurement of the surface-tension of solids. R. Loman and N. P. Zwikker. *Physica*, **1**, 1181–1201 (1934).—Antonow's rule is stated in the form: interfacial tension equals surface tension of liquid less surface tension of solid. Using water and mercury as calibrating liquids, the rule is confirmed and values of surface tension are found for 56 stones, minerals, and ores, 9 steels, and for plate glass and quartz. The method of cleaning has a pronounced influence upon the measured values, but 120 dynes/cm. are derived for glass and 137 dynes/cm. for polished quartz. Sixty-one references. C.J.P.

Viscosimetry of slags. B. P. Selivanov. *Metallurg*, **10** [3] 82–89 (1935).—The theoretical foundations of viscosimetry are briefly discussed. Seven methods of determining the viscosity of slags are briefly outlined. The viscosimeter of the author's system (rotating type) is described. Its advantages and defects are enumerated. S.I.P.

PATENTS

Preparation of lead borate. G. E. Sievert. U. S. 2,014,148, Sept. 10, 1935 (July 18, 1933).—A method of producing lead borate within an electrolytic cell is characterized by having a lead anode and metallic cathodes separated from each other by diaphragms through which electric current may flow, thereafter continuously introducing a boric acid containing electrolyte into the space occupied by the cathodes and continuously withdrawing the electrolyte from the space occupied by the anode, the withdrawn electrolyte containing lead borate.

Zirconium silicon alkali metal composites and methods of making. C. J. Kinzie (Titanium Alloy Mfg. Co.). U. S. 2,013,857, Sept. 10, 1935 (July 20, 1932). The method of making a zirconium silicon alkali metal composite comprises heating zirconium-containing material mixed with a strongly alkaline alkali-metal compound to substantial decomposition to form an acid soluble alkali metal zirconium silicate and treating the silicate with citric acid to obtain a citrate along with zirconium and silicon compounds that remain stable in the fluid and stabilized solution.

General

Adelaide Centennial Exhibition. H. E. Winterbottom. *Clay Prod. Jour. Australia*, **2**, 7 (July, 1935).—The Exhibition is to be held at Adelaide (S.A.) March 20 to May 16, 1936. W., who is organizing secretary, invites potters to exhibit. H.H.S.

Ceramics in Japan. Charles E. Mullin. *Chem. Markets*, **32** [1] 39–42 (1933).—The industries of Japan are more extensively and better developed than those of any other part of the Far East, but they lack originality. A history is given of the ceramic industry in Japan, whose beginning dates back to before B.C. 660. Although labor conditions are not of the best, modern chemical processes and methods are used. Several higher technical schools give specialized courses in ceramics, and the government furnishes assistance to ceramics manufacturers. The glass industry seems to have begun around A.D. 300 and the cement industry as recently as 1871. M.J.H.

Development and prevention of silicosis. Bochum. *Z. Tuberk.*, **72**, 108–12 (1934); *Münch. med. Wochschr.*, **82**, 33–36 (1935); *Klin. Wochschr.*, **14**, 26–27 (1935); *Ind. Hygiene Abs.*, **17** [3] 57 (1935).—These reviews deal with the production of silicosis from the standpoint of mineralogy (Udluft), the technical basis for the quantitative determination of stone dust (Jötten), and the progress of silicosis and its medical control (Reichmann and Schürmann). Among 500 cases of fatal silicosis, 63.7% of the deaths were from tuberculosis and 36.3% from damage to the right heart. Lehmann speaks of the "importance of the nose in the development of pneumoconiosis" (*Ceram. Abs.*, **14** [8] 203 (1935)). As a pathological-anatomist, di Biasi, speaking on tuberculosis and silicosis, on the basis of his experience with 2400 autopsied cases of silicosis (1929 to mid-1934), says there is a progressive silicosis, the worst changes of which are not influenced by tuberculosis; tuberculosis accompanied the silicosis in 65% of the most severe cases. Böhme concludes that social stratum, living standards, and tuberculosis prevalence in the neighborhood are important factors in determining the rate of spread of tuberculosis in an industry. The moment when tuberculosis superimposes itself on silicosis can be determined by X-ray. Tuberculosis and stone dust often act together to spread fibrotic formation and thus accelerate the spread of tuberculosis. Other references are made to the prevention of dust and sickness in the porcelain industry, in stone-cutting, grinding, and mining. In mining, approximately 100 to 300 "Minimax" foam apparatus are used for the dust control in drilling. E.J.V.

Determination of siliceous particles and of coal particles in the lungs. Ernest Kahane. *Ann. med. legale criminol. police sci.*, **15**, 102–107 (1935); *Chem. Abs.*, **29**, 4695 (1935).—For the determination of siliceous particles treat 200 g. of suitably divided tissue in a 2-liter flask with 100 cc. of HNO_3 (density 1.39, freed from siliceous particles by redistillation) and 70 cc. H_2SO_4 (density 1.81); when foaming subsides, heating may be started without any particular precautions. Add a few cubic centimeters of HNO_3 periodically as required; when the temperature reaches 170°, add successive portions of a 1:2 mixture of HNO_3 and $HClO_4$ (density 1.61, redistilled to remove siliceous particles); when a perfectly colorless solution, free from supernatant fat, is obtained, let cool, dilute with

150 cc. H_2O, boil 10 min., filter on an ashless filter, wash with boiling 10% HCl and then with boiling H_2O, dry, ignite in a Pt crucible, and weigh to obtain the total of the siliceous particles; SiO_2 is then obtained by volatilizing with HF. For the determination of coal particles, treat 200 g. of tissue with 200 g. HNO_3 and heat cautiously; when foaming subsides boil 1 hr., cool, filter, and wash, taking care that the solidified fat remains in the flask; treat the residue in the flask with 4 × 50 cc. Me_2CO, decanting each time through the filter, and wash thoroughly with hot H_2O; boil the filter and its contents for 10 minutes with 30 cc. fuming HNO_3 (density 1.49), cool, dilute with 50 cc. H_2O and 50 cc. Me_2CO, filter through double counterpoised filters, wash with Me_2CO and then with 1:1 Me_2CO-H_2O mixture, dry, weigh, and incinerate, the loss giving coal particles. With amorphous C (carbon black), the results are about 10% too high.

Distribution of siliceous dust in the lungs. Georges Antoine. *Ann. med. legale criminol. police sci.*, **15**, 108–25 (1935); *Chem. Abs.*, **29**, 4695 (1935).—By Kahane's method (see preceding abstract) considerable variations were found in duplicate determinations carried out on different portions of the same lung that had been cut up into relatively large pieces. By careful and repeated chopping, the duplicates could be made to agree within 20%; this is satisfactory in view of the extreme variability of the siliceous-particle content of different lungs. In a normal individual, the total SiO_2 impregnation of the whole lung increases with the age of the subject. In the same lung SiO_2 impregnation decreases with the age of the subject, decreases from the upper to the lower lobe, and is greater in the region of the hilum than in the upper lobe. The SiO_2 impregnation of the pulmonary tissue proper in the region of the hilum is the same as the average SiO_2 impregnation of the remainder of the pulmonary parenchyma, while the ganglions have a much higher SiO_2 content (chemical methods thus confirm this histologically established fact) which may reach 14.5 times that of the pulmonary parenchyma. The SiO_2 content of the siliceous particles isolated from the lungs of different individuals varies within fairly narrow limits (86 to 94%).—In the same individual, the SiO_2 content of the particles from different regions of the lung is relatively constant.

Dust collection in the foundry. S. D. Moxley. *Amer. Foundrymen's Assn.* (Preprint), No. 35-17, 16 pp. (1935).—The dust-collection problems consist of three phases, apprehension, collection, and disposal. Each phase is discussed; types of equipment are shown and compared; and dust characteristics are described. Under collection, seven types of equipment are listed and discussed. The engineer and foundrymen should properly analyze the problem at hand and ascertain the degree of fineness of dust it is expected to collect before choosing the collector. H.E.S.

Dust problem in air conditioning. F. B. Rowley. *Heating, Piping & Air Conditioning*, **7** [6] 293–99 (1935).—Methods of measuring dust in the air are reviewed. Tables give the results of (1) dust counts taken at different sections of the air path, (2) counts for samples taken with a stationary and moving orifice, (3) counts of the same air by water impinger and by viscous impinger, and (4) counts for samples taken at intervals of 2 min. The efficiency rating of dust cleaners is discussed. The results of efficiency tests by the dust-count method are given for four filters. J.L.G.

Graphic method for determination of true dip in pits. Norman E. Weisbord. *Bull. Amer. Assn. Petroleum Geol.*, **19** [6] 908–11 (1935).—Angle and direction of apparent dips are read on adjacent sides of the pit. By adjusting a scale to these measurements, the true dip of the stratum can be obtained. G.M.H.

Pottery as cure for unemployment. Editorial. *Clay Prod. Jour. Australia*, **2**, 3 (July, 1935).—Government expenditure on sewerage schemes is becoming highly regarded in Britain and Australia as a cure for unemployment. Each dollar spent in this way means more than a dollar diverted to reproductive industry by the purchase of pipes, their installation, etc. H.H.S.

Researches on dust in plants manufacturing grog ware. Koelsch. *Reichsarb.-Bl.*, **3** [2] 12–16 (1932); abstracted in *Referatkartei Silikatliteratur*, No. 472 (1934).—The effect of dust on the health of workers in grog-ware plants is discussed. M.V.C.

Sodium aluminate in water softening. H. Lewis. *Mech. World*, **97** [2527] 555–56 (1935).—The addition of sodium aluminate during the softening of water by the lime-soda process is beneficial, coagulating the magnesium hydroxide constituent of the precipitate which, due to its colloidal properties, is the cause of "after-precipitation." Since sodium aluminate has no effect, however, on the settling rate of calcium carbonate, the advantages gained by its use are specific to the treated water. Sodium aluminate can be used to remove silica from water, preventing the formation of exceedingly hard silica scales. A minor use is in de-oiling practice. See also "Water—" *Ceram. Abs.*, **14** [7] 176 (1935). E.J.V.

Studies of refractory materials. IX. The conditions of using pyrometric cones (II). Minoru Nakamoto and Tadashi Sakata. *Jour. Jap. Ceram. Assn.*, **43** [508] 201–208 (1935).—Experiments were made to find what influence the method of setting the cone on the plaque and its depth in the plaque had on the temperature at which cone 10 starts to bend and falls flat in a wood-fired commercial porcelain kiln. Cones made in Germany, Tokyo, and Kyoto were used. They were set on the plaques in four ways (1) on edge perpendicular to the plaque (*E*), (2) the numbered surface perpendicular to the plaque (*P*), (3) the surface 80° to the plaque (80°), and (4) the surface 75° to the plaque (75°). The depth of setting was 6 and 12 mm. In both the initial and final bending, the order was 75°, 80°, *E*, and *P*, although the order of *E* and *P* was somewhat obscure, especially in the initial bending. With the 12 mm. setting, the initial bending occurred later and the subsequent bending proceeded faster than in the case of the 6 mm. setting. S.K.

Testing of clay products. T. R. Lynman. *Refrac. Jour.*, **10** [11] 473 (1934).—Many tests for determining the usefulness of a clay are discussed. The tests included are plasticity, shrinkage, chemical analysis, load test for refractories, and permeability. The general method of procedure for making each test is given, and the interpretation of some of the data are discussed. M.C.S.

BOOKS

Chemical Formulary. Vol. II. H. Bennett. D.

Van Nostrand Company, New York, 1935. 570 pp. Price $6.00. An exhaustive compilation of working formulas used commercially in preparing a wide variety of chemical and pharmaceutical products, including drugs, resins, gums, waxes, polishes, plastics, metals and alloys, lubricants, oils, insecticides, disinfectants, ink, ceramic materials, emulsions, cosmetics, cleaners, and soaps. Information pertaining to patent laws on chemical compounds, trade-named chemicals, and suppliers of many chemicals is also given. The information included in this book is, for the most part, thorough and is easily understandable. The book should be included in every scientific library. For Vol. I see *Ceram. Abs.*, **14** [5] 130 (1935).

M. C. SHAW

Energo-Capacious Manufactures. ACADEMY OF SCIENCES OF U.S.S.R. Publishing House of Academy of Sciences, Leningrad, 1934. 288 pp. Price 12R. This volume includes a series of ten papers, nearly half of the volume being devoted to silicate manufactures. **Silicate industry.** V. A. KIND AND S. D. OKOROV. Pp. 113–17. To the silicate industry belongs the manufacture of binding materials (cements) and ceramics with its branches (brick, faience, porcelain, refractories, and sheet, plate, bottle, etc., glass).

The amount of fuel used in Portland cement manufacture (in calories per kg. of product) depending on the method of manufacture is as follows:

	Method	Cal./kg. product
(1)	Wet method in rotary furnace	2060
	Wet method with filters for dewatering slime installed	1725
	Wet method using heat of outgoing gases	1450
(2)	Dry method in rotary furnace	1950
	Dry method using heat of outgoing gases	1525
(3)	Automatic shaft kilns	1500

The amount of electric energy used for cement manufacture in modern mechanized plants with rotary furnaces, depending on the scale of manufacture (from 1 to 6 million barrels per year) is 97 to 102 kw.-hr./T. In cement manufacture using shaft furnaces, the specific expenditure of electrical energy is reduced to 91 kw.-hr./T. produced. The expenditure of electrical energy per ton of alumina cement is 700 to 800 kw.-hr. without reduction of silica to remove it from the batch. This expenditure is increased to 2000 to 2500 kw.-hr./T. by reducing the silica. In "common red" brick manufacture the expenditure of fuel (in modern mechanized plants) for drying and firing is 400 to 440 cal./kg. of product. The expenditure of electrical energy is 20 to 22 kw.-hr./T. Grog refractories require (in modern plants) a fuel expenditure of 1300 cal./kg. and electrical energy of 70 kw.-hr./T. Silica brick take 2100 to 3500 cal./kg. and 50 to 75 kw.-hr./T. Magnesite brick take 4900 cal./kg. and 70 kw.-hr./T. For household porcelain 12,250 to 30,400 cal./kg. and electric energy amounting to 270, 570, and 725 kw.-hr./T. are required. For sanitary faience, 3750 to 15,400 cal./kg. and electric energy of 980 kw.-hr./T. are needed. For sheet glass, 13,860 to 16,000 and for bottle glass 8890 to 9333 cal./kg. are necessary. In Fourcault plants 7000 to 9800 cal./kg; for bottles on Lynch machines, 5100 cal./kg. The electrical energy for a Fourcault plant and for a bottle plant using Lynch machinery is 72 kw.-hr. **Glass industry.** M. A. BESBORODOV. Pp. 167–202. The separate elements of prime cost of the different kinds of glass manufacture by hand and by machinery are considered. Figures on the output of different kinds of glasses from 1928 to 1930 are given. The basic processes of glass manufacture are discussed. Three separate sections deal with energo-capacity of gas producers and glassmelting furnaces, energo-capacity of window-glass manufacture, and energo- and electro-capacities of bottle manufacture. In different types of furnaces, the expenditure of heat for melting is from 5.3 to 15%. The expenditures of heat occur as follows: 8.6 to 18.8% in ash, 25 to 49.9% in waste gases, 2.5 to 10.3% in incomplete combustion, 21.1 to 52.6% in radiation, and 1.8 to 2.5% in the finished glass. The expenditure of fuel (7000 cal./kg.) in kg. per kg. of glass in German regenerative pot furnaces fluctuates according to the number of pots, the capacity of glass in the pots, and the proportion of cullet between 0.81 and 5.0. To manufacture 1 kg. glass in pot furnaces, it is necessary to spend an average of 7000 to 20,000 calories (according to the grade of glass and the amount of heat installations). Tank furnaces are more efficient. Dralle in 1911 gave 1.18 to 1.51 per unit of glass as an average of the fuel expenditure of 11 furnaces. Maurach in 1925 gave the average figures as follows: 1 kg. window glass requires from 0.9 to 0.95 kg. fuel (heating value 7000 cal./kg.); green bottle glass takes 1.05 to 1.15 kg. To cover the expenditure of heat for annealing, it is necessary to add 12.5% to these figures. Window glass by Fourcault machines requires 1200 kg. fuel (7000 cal./kg.) per T. of glass; for heating up a Fourcault channel, 200 to 220 kg. fuel/T. of glass. The expenditure of electrical energy per machine is 3 h.p. This represents 30% of the total expenditure of energy in the plant. **Ceramic industry.** A. K. FREBERG. Pp. 203–33. Ceramic ware are classified. The amount of fuel used in different types of furnaces is given. The annual requirement of a "common red" brick plant with a yearly output of 50,000,000 brick is 9000 to 10,000 T. of fuel and 3,250,000 to 3,500,000 kw.-hr. of electrical energy. The flow sheet of grog refractories manufacture is given. A grog refractory plant with a yearly output 200,000 T. requires 41,500 T. of coal (0.21 T. of coal/T.) and electrical energy 16,000,000 kw.-hr. (80 kw.-hr./T.). The flow sheet of silica-brick manufacture and the amount of fuel used in different kinds of furnaces is discussed. The need of fuel for a silica-brick plant with a yearly output of 100,000 T. is 34,000 T. (0.34 T. fuel/T.) and 7,000,000 kw.-hr. electric energy (70 kw.-hr./T.). The flow sheet of whiteware (porcelain and faience) manufacture is given. The expenditure of fuel for firing 1 T. of porcelain fluctuates between 0.65 and 3.25 T., depending on the type of furnace and for faience, between 0.55 and 1.5 T. S. I. PERKAL

Pneumonokonioses (Silicosis) Literature and Laws of 1934. GEORGE G. DAVIS, ELLA M. SALMONSEN, AND JOSEPH L. EARLYWINE. Chicago Medical Press, Chicago, 1935. vii + 490 pp. Price $10.00. In an earlier volume (*Ceram. Abs.*, **13** [9] 246 (1934)) these authors issued a reference list of 2768 books and papers and a digest of all statutes and cases pertinent and of record prior to 1934. The present volume gives abstracts of 396 of the most important papers and publications which appeared during 1934 and also a reference list of publications which ap-

peared prior to 1934 but were not included in the reference list issued in the first volume. This new volume also gives a digest of statutes and cases of record in the year 1934. A subject and author index is well done. This digest of the 1934 literature, statutes, and cases, used in conjunction with the previous publication, forms an entirely adequate basis for determining the present status of the knowledge and of the law on this occupational disease.

ROSS C. PURDY

What Every Worker Should Know. Glass Blower. G. A. KOVTUNENKO. State Pub. House of Light Ind., Moscow and Leningrad, 1935. 64 pp. Price 80k. This textbook on the technical minimum for workers of the glass industry adds nothing new to the basic literature of glass technology, but it provides an adequate elementary acquaintance with glass manufacture. Sixty-eight control questions are included in the text. S. I. PERKAL

PATENT

Ceramic covering for electrical flat-irons. STOTZ-KONTAKT GES. Brit. 429,738, June 19, 1935 (Nov. 18, 1933).

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T. Z. Metallbearbeitz
Umschau
United States Public Health Reports
Zeitschrift Deutschen Geologischen Gesellschaft
Zeitschrift Pflanzenernährung Düngung und Bodenkunde
Zeitschrift Praktische Geologie
Zentralblatt Gewerbehygiene & Unfallverhütung
Ziegelwelt

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1936 ANNUAL MEETING
American Ceramic Society
COLUMBUS, OHIO
March 29 to April 4

SCHEDULE OF MEETING PLACES

	Saturday Mar. 28	Sunday Mar. 29		Monday Mar. 30		Tuesday Mar. 31		Wednesday Apr. 1		Thursday Apr. 2	Friday Apr. 3	Saturday Apr. 4
	All Day	All Day	Night	All Day	Night	All Day	Night	All Day	Night	All Day		
Trustees	Wallick Suite		President's Reception—Concert—Deshler Ball—8:00	Wallick Suite	Supper—Entertainment—7:30—Deshler Ball	Wallick Suite	Edward Orton, Jr., Lecture—9:00—Deshler Ball	Wallick Suite	Dance—Floor Show—Neil Ball	Wallick Suite		
Trustees and Committees		Deshler A. B. C.										
Art Division				General Meetings—Deshler Ball		Neil Blue		Neil Blue		Extra Division Sessions—Tour of Columbus Claycraft—Enamel—and Glass Factories Ohio State University—Battelle—Orton Lab.	Zanesville Roseville Crooksville	
Enamel Division						Deshler A. B. C.		Deshler A. B. C.			Newark	
Glass Division						Neil Ball		Neil Ball			Newark Lancaster	
Materials and Equipment												
Refractories						Deshler Ball		Deshler Ball				
Structural Clay						Neil Red		Neil Red			Claycraft New Lexington New Straitsville	
Terra Cotta						Neil Garden		Neil Garden				
White Wares						Neil Jr. Ball		Neil Jr. Ball			Zanesville Crooksville	
Registration		← Deshler Assembly Room →										
						← Neil Mezzanine →						
Publicity and Editorial		← Room 21 Deshler →										
						← Neil Mezzanine →						

EXECUTIVE COMMITTEE

George A. Bole, Manager, Edward Orton, Jr., Ceramic Foundation, 1445 Summit St., Columbus, Ohio.
Clyde E. Williams, Battelle Memorial Institute, Columbus, Ohio.
C. Forrest Tefft, P. O. Box 866, Columbus, Ohio.
Earl Crooks, Crooksville China Co., Crooksville, Ohio.
Frank Ransbottom, Robinson-Ransbottom Pottery Co., Roseville, Ohio.
Arthur S. Watts, Lord Hall, Ohio State Univ., Columbus, Ohio.

COMMITTEE CHAIRMEN

Meeting Service: John D. Sullivan, Battelle Memorial Institute.
Entertainment: Ross C. Purdy, 2525 N. High St.
Ladies' Entertainment: Mrs. Ellsworth P. Ogden, 1957 Chelsea Road.
Plant Trips: J. L. Carruthers, Lord Hall, Ohio State Univ.
Publicity: Clyde E. Williams, Battelle Memorial Institute.
Exhibits: Arthur S. Watts, Lord Hall, Ohio State Univ.
Finances: C. Forrest Tefft, P. O. Box 866.